PB-214 176

Prediction of the Effects of Transportation Controls on Air Quality in Major Metropolitan Areas

TRW, Inc.

prepared for
Environmental Protection Agency

NOVEMBER 1972

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APTD-1363

PREDICTION OF THE EFFECTS OF TRANSPORTATION CONTROLS ON AIR QUALITY IN MAJOR METROPOLITAN AREAS

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Research Triangle Park, North Carolina 27711

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APTD-1363

PREDICTION OF THE EFFECTS OF TRANSPORTATION CONTROLS ON AIR QUALITY IN MAJOR METROPOLITAN AREAS

Prepared by

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Contract No. 68-02-0048
Task Order 6

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Prepared for

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Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711
November 1972

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Office of Air Programs Publication No. APTD-1363

ACKNOWLEDGEMENT

TRW received considerable assistance in the collection and compilation of the data contained in this report. In particular, Mr. Joseph Revis of the Institute of Public Administration was responsible for the collection and preliminary interpretation of the traffic information from each of the six metropolitan areas. Many local and state agencies supplied data and critical analysis to the study. Continual project direction and guidance were provided by Mr. Gary Hawthorne of the Environmental Protection Agency's Land Use Planning Branch.

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1.0 INTRODUCTION

The objectives of the Six Cities Transportation Analysis Project are to evaluate transportation controls in the reduction of motor vehicle emissions and to predict the impact of the expected emission reductions on air quality in six metropolitan areas.

In the companion report entitled "Evaluating Transportation Controls to Reduce Motor Vehicle Emission in Major Metropolitan Areas,"* TRW and Institute of Public Administration/Technicron analyzed the various alternative transportation control strategies. Transportation controls were defined broadly, but greatest attention was given to those controls capable of being implemented by 1977. This analysis led to a general appreciation of the applicability of the various alternatives. The evaluation was based on a survey of existing published and unpublished data and upon discussions with knowledgeable authorities in the areas of transportation control and air pollution. This evaluation provided a general analytic framework upon which the more specific analysis of the six metropolitan areas was prepared.

The following report details the data collection and specific analysis performed in each of the six cities. The sources of transportation and other data are identified and the limitations of the data base are described. Analytic projections of emission rates and predicted concentration levels are given for each of the defined transportation control conditions.

Section 2.0 describes the general analytic methodology used in the analysis of the transportation data. Section 3.0 describes the analyses specific to each metropolitan area. Section 4.0 presents a somewhat more detailed discussion for Washington, D. C., which was used as a test case for development of analytic procedures.

*(also called the IPA/TRW Report)

2.0 GENERAL METHODOLOGY

2.1 SUMMARY

Transportation data in the form of vehicle miles traveled (VMT) by geographic areas have been used as the basis for calculating emission rates and air quality. The methodology involved:

Step 1 - Assignment of VMT and speed to elements of a grid network. This required superimposing a rectangular grid network consisting of one mile squares or one kilometer squares over a base map of the metropolitan area and summation of VMT from each of the individual roadways which may fall within one of the small grids to obtain the total VMT for each element or small grid in the grid network. The speed for each grid of the grid network is obtained by averaging the speeds from each element or roadway within the grid for each time period required, using the VMT along each element of roadway as a proportioning factor. In this manner the many vehicular sources moving within an individual grid can be represented by a single stationary source, which produces the same amount of emissions, equal to the size of the individual grid. This equivalent source is called an area source because the emissions from the grid or area source are now considered as evenly distributed or evenly produced over the entire area of the individual grid.

Step 2 - Use of vehicle emission factors to calculate emissions on a per-grid basis.

Step 3 - Conversion of emission rates to pollutant concentration on a per-grid basis by the method of Gifford and Hanna(1).

Step 4 - Application of transportation control strategies to the data base to obtain predicted concentration patterns for each control strategy for the year 1977.

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(1) S. R. Hanna and F. A. Gifford, Jr., "Urban Air Pollution Modelling," Presented at 1970 International Air Pollution Conference of the International Union of Air Pollution Prevention Associations, ATDL Contribution No. 37.

The resulting concentrations are presented graphically as isopleths over a map of the metropolitan area. Pollutants considered were carbon monoxide, hydrocarbons, and oxides of nitrogen, with carbon monoxide being of primary interest.

2.2 TRANSPORTATION METHODOLOGY[2]

2.2.1 General Guidelines

In undertaking the phase of work involving evaluation and testing of potential transportation control candidates, certain areas of general agreement were reached with the Environmental Protection Agency. These ground rules were required because of the short time available to complete the work. Specifically, the following guidelines were used in developing the methodology of the project analysis:

1. Attention was to be given to automobile air pollution problems arising from travel into, out of, and within the central business district (CBD) during the peak rush hours during a typical work day.
2. In addition to the focus on the CBD, the data would be confined to that available from existing transport demand models used in each of the six cities.
3. The strategies that were tested were selections from the findings of the TRW/IPA Report [3] and would include only three specific strategies: inspection and maintenance, traffic flow controls, and motor vehicle/public transport improvements (combined strategies). These strategies were judged to be the most implementable and to produce reasonable degrees of emission reduction.

---

[2] A large number of cooperating agencies provided data for the analysis; without their cooperation this phase of the project would have been impossible. However, they are in no way responsible for the adjustments, alterations, or manipulations undertaken of the data for the purpose of the analysis. Any adjustments of interpretations of their data are the responsibility of the project.

[3] Institute of Public Administration and Teknekron, Inc., in cooperation with TRW Inc., Evaluating Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, Washington, D. C., November 20, 1972.

2.2.2 Specific Approach

From urban transportation demand models (the traffic assignment portions), VMT and speed data were obtained. Wherever possible, VMT and speed data were obtained by zone. If no zonal information was available, zonal estimates were made(4). However, the emission levels are actually used as average zonal values and are rough approximations rather than point measures. In addition, the factors used to convert VMT and speed data into emission levels themselves introduced errors which are of at least equal magnitude to those introduced by allocation of link VMT into zones.

Because the requirements of the project were to develop eight-hour and one-hour maximum levels of emission, VMT data had to be converted to these units of time. Most of the VMT and speed information supplied (in the form of computer printouts) was for a 24-hour average weekday (in some cases peak-hour data were available) and, therefore, had to be adjusted to estimate the eight-hour and one-hour maximum. These estimates were made utilizing daily hourly traffic counts made available by the traffic departments and transportation planning agencies in each of the cities.

Most of the traffic assignment data provided had base years in 1968 and 1969. These same models generally provided projected values for VMT (and very often speeds) for the year 1980 and beyond. Interpolations, therefore, had to be made for the year 1977. In making these interpolations employment, residential, and population data were used wherever available. Where these data or growth models were not available, interpolations were generally based on straight line assumptions.

---

(4) There is obviously a problem in allocating VMT along those segments of the network which serve as boundaries to zones. The allocation of specific link VMT to the zones on each side of the link boundary reduces the reliability of the analysis used in describing the emission reduction characteristics of each of the proposed strategies.

Most of the traffic assignment models developed their projections using a number of alternative assumptions with regard to the characteristics of future highway networks and the mix between highway and transit. For the purposes of the analysis of this project, only the most conservative highway construction assumptions were used. The traffic assignment data used for each of the cities was for the highway alternative which assumed the smallest amount of highway construction -- in the jargon of urban transportation planners -- for "committed systems."

In a number of cities speed information had to be estimated for each of the zones. Where this was done, the speeds were based upon link-node data using weighted averages weighting the respective speeds using link volumes as weights.

2.3 MOBILE SOURCE POLLUTANT CONCENTRATION PROGRAM (MSPC)

The MSPC program handles the computations included in Steps 2, 3, and 4 (Section 2.1). This program allows the use of the more complex form of the Gifford-Hanna model described below.

The MSPC utilizes local traffic data and meteorological data to predict pollutant concentration patterns for three mobile source pollutants. The program input and output are oriented to a rectangular grid network which overlays the city of interest. The results are presented in tabular form as the average concentrations for each element of the grid network. Punched card output was used to produce concentration isopleths or concentration density maps which were overlaid on a map of the metropolitan area to give a visual representation of the spatial distribution of the pollutant of interest.

The program was also used to evaluate the effect of mobile source pollutant control strategies such as direct or indirect vehicle emission controls or traffic controls.

2.3.1 Program Input

Three groups of input data are required (traffic data, meteorological data, and emission factors for each pollutant.

- Traffic Flow Data

The resulting grid network of VMT and speed from Step 1 above provide the basic traffic flow data required for emission calculations.

To correspond with the time periods specified by the National Ambient Air Quality Standards, peak one-hour and peak eight-hour VMT are required. For comparison with the ambient air quality standards for hydrocarbons and nitrogen dioxide, a Larsen transformation was used to convert estimates to three-hour and annual averages, respectively. Where these data are not available, they were estimated as percentages of the 24-hour VMT by using traffic count information at various stations within the area. The program applied this percentage where necessary to obtain the appropriate data format. Particular streets may vary significantly from the mean values obtained by this procedure; however, the allocation of VMT to grids as described above tends to minimize the effect of individual streets on the predicted concentrations values for the individual grid.

Traffic speed data on a per-grid basis are required as an adjustment to the average vehicle emission factors. Carbon monoxide and hydrocarbon emissions decrease with increasing average vehicle speed; therefore, the emission factors must be adjusted to be more realistic. EPA has published emission factors curves(5) as a function of average vehicle speed for carbon monoxide and hydrocarbons. These curves are incorporated in the program.

---

(5) "Compilation of Air Pollutant Emission Factors (Revised)" Environmental Protection Agency, Office of Air Programs, February 1972, Office of Air Programs Publication No. AP-42.

The modal split of VMT must be considered. i.e., what is the proportion of cars, buses, and trucks comprising the total VMT. Data on the modal split are not typically available on a detailed basis; therefore, this factor is most readily accounted for in the formulation of area emission factors as discussed below.

- Meteorological Data

According to the Gifford-Hanna diffusion model used by the program, concentrations have a strong inverse relation to wind speed. This implies that concentrations will be greatest during periods of stagnation or very low wind speed. This inverse relation (see Gifford-Hanna equation, page 2-8) makes it clear that zero wind is not an allowable condition. The lowest practical value of wind speed utilized has been 2.5 meters/second (based on discussion with meteorologists).

Wind direction is also a necessary input to the program because the model accounts for contribution by upwind grids to the total concentration at an individual grid. Several cases of wind speeds and directions were input to the program for each metropolitan area. These cases were represented by actual seasonal data (wind roses) or conditions considered typical of high pollutant concentrations for the area. A frequency distribution analysis of wind data for peak-hour and maximum eight-hour time periods would be required to obtain a truly representative wind distribution pattern for each city. Although hourly wind data are available for each of the metropolitan areas considered, time did not permit this detailed analysis of the wind data. The annual average wind speed and direction and other "typical" wind speeds and directions were normally used for each city. It should be noted that because the traffic data (24-hour VMT, eight-hour VMT, peak-hour VMT) have no seasonal component, the spatial distribution of concentrations (the isopleth patterns) are a result of the applied wind direction only and the numerical concentration values may not truly be compared to the seasonal ambient data because they are dependent only on wind speed and direction.

- Emission Factors

EPA has developed a computer program to produce emission factors for the entire vehicle population for a given metropolitan area for any calendar year from 1960 to 1990 for which vehicle age-type distribution data are available. Emission factors are subject to revision as required by changes in vehicles, control devices, "representative" driving cycles, and measurement techniques.

- The Gifford-Hanna Diffusion Model

Many modeling approaches of varying degrees of complexity have been developed. Consideration of available models led to selection of the Gifford-Hanna model on the basis of ease of use and reasonable agreement with more complex models(6).

The Gifford-Hanna model assumes that the emissions from an area the size of a city can be represented by a gridwork of area sources with each source or grid having an emission strength Q (amount/m^2-sec). Q is assumed constant with time and "relatively smooth" in distance (i.e., Q does not vary by more than a factor of 10 from grid to grid). The crosswind component of diffusion is then neglected in comparison with the vertical component which is assumed to be Gaussian. The result is:

---

(6) S. R. Hanna, "Simple Methods of Calculating Dispersion From Urban Area Sources," Contribution No. 46 from the Atmospheric Turbulence and Diffusion Laboratory.

$$\chi = \sqrt{\frac{2}{\pi}}\,\frac{1}{u}\,\frac{(\Delta x/2)^{1-b}}{a(1-b)}\left\{Q_o + \sum_{i=1}^{N} Q_i\left[(2i+1)^{1-b} - (2i-1)^{1-b}\right]\right\}$$

where χ = concentration (mg/m^3)

u = wind speed (m/sec)

Δx = grid side length (m x 10^3)

Q_o = central grid source strength (g/m^2-sec)

N = 10

a and b = empirical constants of urban stability averaging 0.15 (meters^{1-b}) and 0.75, respectively.

Figure 2-1 shows the Gifford-Hanna method for combining source grids for various wind directions. This method accounts for the contribution of upwind sources to the concentration at a given grid. The Gifford-Hanna model is a form of Gaussian plume rather than a numerical integration model. It does not adequately describe the accumulation of pollutants that may occur due to prolonged stagnation conditions or due to the back-and-forth or "sloshing" action apparent in Los Angeles or Denver basins. Therefore, the maximum emissions and resultant "worst case" concentrations predicted by application of the model are constrained by the maximum allowable wind speed definition and the maximum emissions input (given by the maximum eight hours and maximum one hour of traffic volume from annual average weekday traffic counts) and may not agree with the "absolute" maximum ambient concentration. Within these constraints the model appears to be a very good predictor of carbon monoxide concentrations (as shown by the comparison with Washington, D.C. ambient data. (See Section 4.3.)

- Stationary Sources

Available stationary source emissions data were included in order to make predicted concentration values more realistic. In the six cities studied, mobile sources contributed from 90 - 99 percent of the carbon monoxide emissions and the impact of the stationary sources on concentrations values was significant only in the vicinity of major point sources.

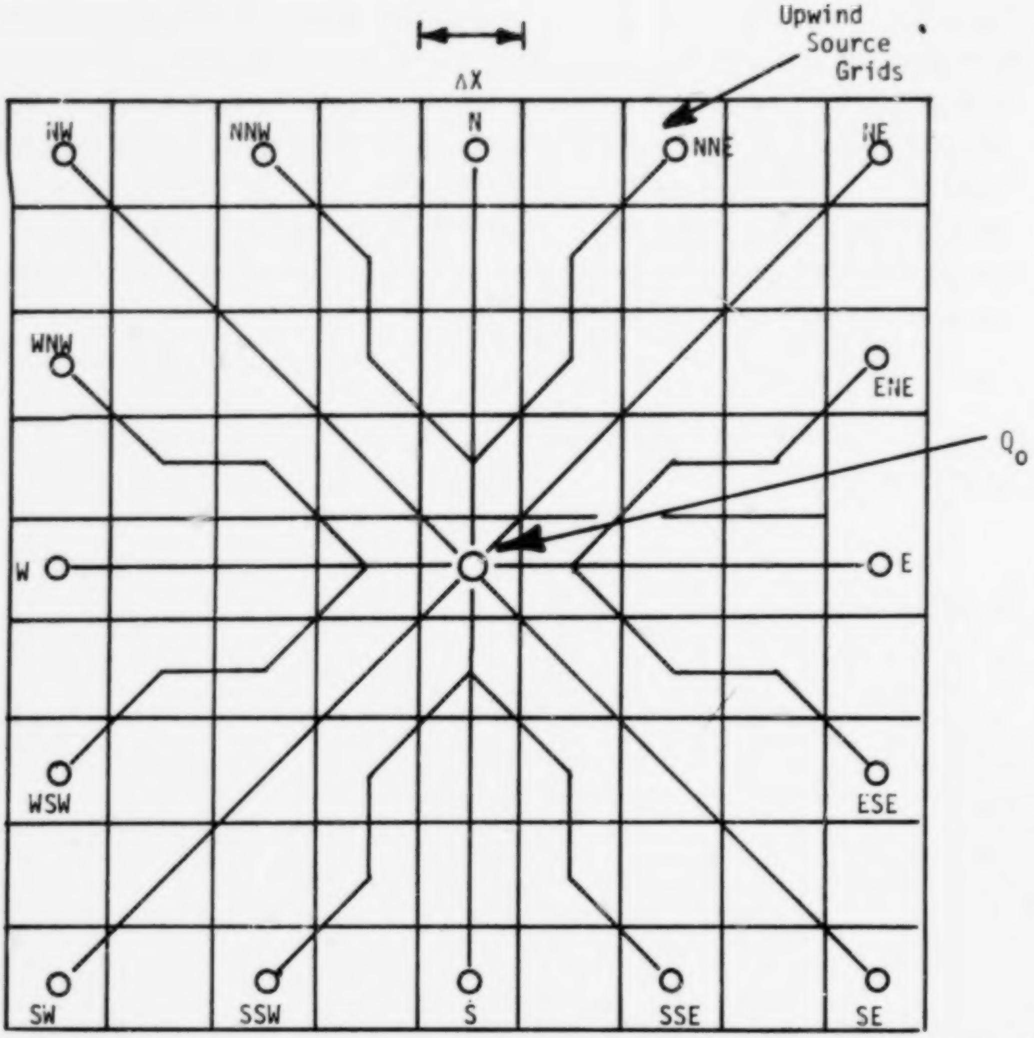
ΔX
Upwind Source Grids
NW
NNW
N
NNE
NE
WNW
ENE
Q_o
W
E
WSW
ESE
SW
SSW
S
SSE
SE

Figure 2-1. Scheme for Combining Rectilinear Source-Grid Squares with Radial Wind Directions (See Gifford-Hanna equation, page 2-8).

Stationary sources represent a major portion of the hydrocarbon and NO_x emissions in the cities studied. It can be seen from the model equation above that the relative impact of large point source emissions on predicted concentration values would be grossly overestimated by the area source model because of the lack of stack height and plume rise considerations. Several procedures were attempted to include these emissions as area sources; however, results are poor. It is recommended that the large point sources be modelled independently using AQDM or a similar Gaussian model and the resultant concentrations could be added to the area source concentrations to obtain a more realistic concentration estimate.

2.3.2 Program Output

A discussion of some program runs will give a representative sample of output

Three transportation conditions (and therefore three complete runs) are considered as follows:

Run No. 1 (Current Conditions - 1968)

Case 1	Average summer wind
Case 2	Average winter wind
Case 3	"Nominal" (west wind at 6 m/sec)
Case 4	"Worst Case" (2.5 m/sec)
Pollutants	CO, HC, NO_x

Run No. 2(Projected Conditions - 1977)
Assuming no additional transportation controls

Case 1	Average summer wind
Case 2	Average winter wind
Case 3	"Nominal" (west wind at 6 m/sec)
Case 4	"Worst Case" (2.5 m/sec)
Pollutants	CO, HC, NO_x

Run No. 3 (Projected Conditions - 1977)
Assuming 25 percent reduction in CO emissions only
from a general inspection and maintenance program

Case 1	Average summer wind
Case 2	Average winter wind
Case 3	"Nominal" (west wind at 6 m/sec)
Case 4	"Worst Case" (2.5 m/sec)
Pollutant	CO only

A sample output for a test run follows (Table 2-1) showing:

1. Annual Emissions (tons/year) for each grid for HC and NO_x and total emissions for a grid network.
2. Emission rates ($mg/m^2/sec$) for each grid for both mobile and total eight-hour and one-hour emissions for CO are given as a sample. Actual listings include HC and NO_x emissions.
3. Pollutant concentrations (mg/m^3) for CO for each of the time periods (in 2. above) for each grid for "worst case" conditions. Actual listings include all cases described above.

```
RUN: TEST CASE                          ANNUAL EMISSION RATES (TONS/YR)

                        ---------CO--------- ---------HC--------- ---------NOX-------

GRID  X(KM)    Y(KM)     TOT EMM   MOB EMM   TOT EMM   MOB EMM   TOT EMM    MOB EMM
  1   307.50  4294.50      215.      215.       37.       37.       17.        17
  2   308.50  4294.50      215.      215.       37.       37.       17.        17
  3   309.50  4294.50      215.      215.       37.       37.       17.        17
  4   310.50  4294.50      215.      215.       37.       37.       17.        17
  5   311.50  4294.50     1304.     1304.      224.      224.      103.       103
  6   312.50  4294.50     1304.     1304.      224.      224.      103.       103
  7   313.50  4294.50     1304.     1304.      224.      224.      103.       103
  8   314.50  4294.50     1304.     1304.      224.      224.      103.       103
  9   307.50  4295.50      413.      413.       71.       71.       33.        33
 10   308.50  4295.50      413.      413.       71.       71.       33.        33
 11   309.50  4295.50      413.      413.       71.       71.       33.        33
 12   310.50  4295.50      413.      413.       71.       71.       33.        33
 13   311.50  4295.50      816.      816.      140.      140.       65.        65
 14   312.50  4295.50      816.      816.      140.      140.       65.        65
 15   313.50  4295.50      816.      816.      140.      140.       65.        65
 16   314.50  4295.50      816.      816.      140.      140.       65.        65
 17   307.50  4296.50      284.      284.       49.       49.       23.        23
 18   308.50  4296.50      284.      284.       49.       49.       23.        23
 19   309.50  4296.50      189.      189.       33.       33.       15.        15
 20   310.50  4296.50      189.      189.       33.       33.       15.        15
 21   311.50  4296.50      277.      277.       48.       48.       22.        22
 22   312.50  4296.50      277.      277.       48.       48.       22.        22
 23   313.50  4296.50      277.      277.       48.       48.       22.        22
 24   314.50  4296.50      277.      277.       48.       48.       22.        22
 25   307.50  4297.50      211.      211.       36.       36.       17.        17
 26   308.50  4297.50      211.      211.       36.       36.       17.        17
 27   309.50  4297.50      211.      211.       36.       36.       17.        17
 28   310.50  4297.50      211.      211.       36.       36.       17.        17
 29   311.50  4297.50      221.      221.       38.       38.       18.        18
 30   312.50  4297.50      221.      221.       38.       38.       18.        18
 31   313.50  4297.50      221.      221.       38.       38.       18.        18
 32   314.50  4297.50      221.      221.       38.       38.       18.        18
 33   307.50  4298.50      215.      215.       37.       37.       17.        17
 34   308.50  4298.50      215.      215.       37.       37.       17.        17
 35   309.50  4298.50      215.      215.       37.       37.       17.        17
 36   310.50  4298.50      215.      215.       37.       37.       17.        17
 37   311.50  4298.50     1304.     1304.      224.      224.      103.       103
 38   312.50  4298.50     1304.     1304.      224.      224.      103.       103
 39   313.50  4298.50     1304.     1304.      224.      224.      103.       103
 40   314.50  4298.50     1304.     1304.      224.      224.      103.       103
 41   307.50  4299.50      413.      413.       71.       71.       33.        33
 42   308.50  4299.50      413.      413.       71.       71.       33.        33
 43   309.50  4299.50      413.      413.       71.       71.       33.        33
 44   310.50  4299.50      413.      413.       71.       71.       33.        33
 45   311.50  4299.50      816.      816.      140.      140.       65.        65
 46   312.50  4299.50      816.      816.      140.      140.       65.        65
 47   313.50  4299.50      816.      816.      140.      140.       65.        65
 48   314.50  4299.50      816.      816.      140.      140.       65.        65
 49   307.50  4300.50      284.      284.       49.       49.       23.        23
 50   308.50  4300.50      284.      284.       49.       49.       23.        23
```

Table 2-1. Sample Output for Mobile Source Pollutant Concentration Program

```
RUN: TEST CASE                               ANNUAL EMISSION RATES (TONS/YR)

                          ---------CO--------- --------HC--------- --------NOX--------

GRID  X(KM)    Y(KM)     TOT EMM     MOB EMM     TOT EMM     MOB EMM     TOT EMM     MOB EMM
  51  309.50 4300.50        189.        189.         33.         33.         15.         15.
  52  310.50 4300.50        189.        189.         33.         33.         15.         15.
  53  311.50 4300.50        277.        277.         48.         48.         22.         22.
  54  312.50 4300.50        277.        277.         48.         48.         22.         22.
  55  313.50 4300.50        277.        277.         48.         48.         22.         22.
  56  314.50 4300.50        277.        277.         48.         48.         22.         22.
  57  307.50 4301.50        211.        211.         36.         36.         17.         17.
  58  308.50 4301.50        211.        211.         36.         36.         17.         17.
  59  309.50 4301.50        211.        211.         36.         36.         17.         17.
  60  310.50 4301.50        211.        211.         36.         36.         17.         17.
  61  311.50 4301.50        221.        221.         38.         38.         18.         18.
  62  312.50 4301.50        221.        221.         38.         38.         18.         18.
  63  313.50 4301.50        221.        221.         38.         38.         18.         18.
  64  314.50 4301.50        221.        221.         38.         38.         18.         18.

TOTAL---------------      29555.      29555.       5084.       5084.       2343.       2343.
```

Table 2-1. (Continued)

```
RUN: TEST CASE
EMISSION RATES (MG/SEC/SQ METER)
POLLUTANT:  CO

GRID     8HR TOT      8HR MOB      1HR TOT      1HR MOB

  1      0.0089       0.0089       0.0192       0.0192
  2      0.0089       0.0089       0.0192       0.0192
  3      0.0089       0.0089       0.0192       0.0192
  4      0.0089       0.0089       0.0192       0.0192
  5      0.0541       0.0541       0.1162       0.1162
  6      0.0541       0.0541       0.1162       0.1162
  7      0.0541       0.0541       0.1162       0.1162
  8      0.0541       0.0541       0.1162       0.1162
  9      0.0171       0.0171       0.0363       0.0363
 10      0.0171       0.0171       0.0363       0.0363
 11      0.0171       0.0171       0.0363       0.0363
 12      0.0171       0.0171       0.0363       0.0363
 13      0.0338       0.0338       0.0754       0.0754
 14      0.0338       0.0338       0.0754       0.0754
 15      0.0338       0.0338       0.0754       0.0754
 16      0.0338       0.0338       0.0754       0.0754
 17      0.0118       0.0118       0.0230       0.0230
 18      0.0118       0.0118       0.0230       0.0230
 19      0.0079       0.0079       0.0155       0.0155
 20      0.0079       0.0079       0.0155       0.0155
 21      0.0115       0.0115       0.0231       0.0231
 22      0.0115       0.0115       0.0231       0.0231
 23      0.0115       0.0115       0.0231       0.0231
 24      0.0115       0.0115       0.0231       0.0231
 25      0.0088       0.0088       0.0188       0.0188
 26      0.0088       0.0088       0.0188       0.0188
 27      0.0088       0.0088       0.0188       0.0188
 28      0.0088       0.0088       0.0188       0.0188
 29      0.0092       0.0092       0.0190       0.0190
 30      0.0092       0.0092       0.0190       0.0190
 31      0.0092       0.0092       0.0190       0.0190
 32      0.0092       0.0092       0.0190       0.0190
 33      0.00 9       0.0089       0.0192       0.0192
 34      0.0089       0.0089       0.0192       0.0192
 35      0.0089       0.0089       0.0192       0.0192
 36      0.0089       0.0089       0.0192       0.0192
 37      0.0541       0.0541       0.1162       0.1162
 38      0.0541       0.0541       0.1162       0.1162
 39      0.0541       0.0541       0.1162       0.1162
 40      0.0541       0.0541       0.1162       0.1162
 41      0.0171       0.0171       0.0363       0.0363
 42      0.0171       0.0171       0.0363       0.0363
 43      0.0171       0.0171       0.0363       0.0363
 44      0.0171       0.0171       0.0363       0.0363
 45      0.0338       0.0338       0.0754       0.0754
 46      0.0338       0.0338       0.0754       0.0754
 47      0.0338       0.0338       0.0754       0.0754
 48      0.0338       0.0338       0.0754       0.0754
 49      0.0118       0.0118       0.0230       0.0230
 50      0.0118       0.0118       0.0230       0.0230
```

Table 2-1. (Continued)

```
RUN: TEST CASE
EMISSION RATES (MG/SEC/SQ METER)
POLLUTANT:  CO

GRID     8HR TOT     8HR MOB     1HR TOT     1HR MOB

 51      0.0079      0.0079      0.0155      0.0155
 52      0.0079      0.0079      0.0155      0.0155
 53      0.0115      0.0115      0.0231      0.0231
 54      0.0115      0.0115      0.0231      0.0231
 55      0.0115      0.0115      0.0231      0.0231
 56      0.0115      0.0115      0.0231      0.0231
 57      0.0088      0.0088      0.0188      0.0188
 58      0.0088      0.0088      0.0188      0.0188
 59      0.0088      0.0088      0.0188      0.0188
 60      0.0088      0.0088      0.0188      0.0188
 61      0.0092      0.0092      0.0190      0.0190
 62      0.0092      0.0092      0.0190      0.0190
 63      0.0092      0.0092      0.0190      0.0190
 64      0.0092      0.0092      0.0190      0.0190
```

Table 2-1. (Continued)

```
RUN: TEST CASE
POLLUTANT CONCENTRATION (MG/CUBIC METER)
POLLUTANT:  CO   CASE: WORST

GRID      8HR TOT      8HR MOB      1HR TOT      1HR MOB

   1       0.7669       0.7669       1.6509       1.6509
   2       0.7669       0.7669       1.6509       1.6509
   3       0.7669       0.7669       1.6509       1.6509
   4       0.7669       0.7669       1.6509       1.6509
   5       2.5847       2.5847       5.5567       5.5567
   6       4.6570       4.6570      10.0093      10.0093
   7       4.6570       4.6570      10.0093      10.0093
   8       4.6570       4.6570      10.0093      10.0093
   9       1.4752       1.4752       3.1269       3.1269
  10       1.4752       1.4752       3.1269       3.1269
  11       1.2025       1.2025       2.5586       2.5586
  12       1.2025       1.2025       2.5586       2.5586
  13       1.8755       1.8755       4.1335       4.1335
  14       2.0882       2.0882       4.6312       4.6312
  15       2.4136       2.4136       5.3303       5.3303
  16       3.5861       3.5861       7.8496       7.8496
  17       1.0143       1.0143       1.9806       1.9806
  18       1.0143       1.0143       1.9806       1.9806
  19       1.0341       1.0341       2.1211       2.1211
  20       0.9843       0.9843       2.0260       2.0260
  21       0.9609       0.9609       1.9786       1.9786
  22       1.0073       1.0073       2.0756       2.0756
  23       1.1278       1.1278       2.3576       2.3576
  24       1.2159       1.2159       2.5639       2.5639
  25       0.7555       0.7555       1.6155       1.6155
  26       0.7555       0.7555       1.6155       1.6155
  27       0.8551       0.8551       1.7561       1.7561
  28       0.8551       0.8551       1.7561       1.7561
  29       0.9541       0.9541       1.9858       1.9858
  30       0.9386       0.9386       1.9490       1.9490
  31       0.8590       0.8590       1.7833       1.7833
  32       0.8782       0.8782       1.8235       1.8235
  33       0.7669       0.7669       1.6509       1.6509
  34       0.7669       0.7669       1.6509       1.6509
  35       0.7625       0.7625       1.6372       1.6372
  36       0.7625       0.7625       1.6372       1.6372
  37       2.6425       2.6425       5.6307       5.6307
  38       3.2169       3.2169       6.8650       6.8650
  39       3.2722       3.2722       7.0063       7.0063
  40       3.2604       3.2604       6.9806       6.9806
  41       1.4752       1.4752       3.1269       3.1269
  42       1.4752       1.4752       3.1269       3.1269
  43       1.2025       1.2025       2.5586       2.5586
  44       1.2025       1.2025       2.5586       2.5586
  45       1.8728       1.8728       4.1250       4.1250
  46       2.0854       2.0854       4.6227       4.6227
  47       2.4495       2.4495       5.3764       5.3764
  48       2.6877       2.6877       5.8881       5.8881
  49       1.0143       1.0143       1.9806       1.9806
  50       1.0143       1.0143       1.9806       1.9806
```

Table 2-1. (Continued)

```
RUN: TEST CASE
POLLUTANT CONCENTRATION (MG/CUBIC METER)
POLLUTANT:  CO   CASE: WORST

GRID     8HR TOT     8HR MOB     1HR TOT     1HR MOB

 51      1.0341      1.0341      2.1211      2.1211
 52      0.9843      0.9843      2.0260      2.0260
 53      0.9609      0.9609      1.9786      1.9786
 54      1.0073      1.0073      2.0756      2.0756
 55      1.1261      1.1261      2.3523      2.3523
 56      1.2142      1.2142      2.5586      2.5586
 57      0.7555      0.7555      1.6155      1.6155
 58      0.7555      0.7555      1.6155      1.6155
 59      0.8551      0.8551      1.7561      1.7561
 60      0.8551      0.8551      1.7561      1.7561
 61      0.9541      0.9541      1.9858      1.9858
 62      0.9386      0.9386      1.9490      1.9490
 63      0.8590      0.8590      1.7833      1.7833
 64      0.8782      0.8782      1.8235      1.8235
```

Table 2-1. (Continued)

A punched card output was submitted to a plotting routine to obtain isopleth maps for each of the pollutants and transportation conditions described in Section 2.3.2.

2.4 STRATEGIES EVALUATION

2.4.1 Strategy 1 - Inspection and Maintenance

Broadly defined, the inspection and maintenance programs involve (1) the inspection of in-use vehicles, (2) the identification of high emitters (and, hopefully, the provision of diagnostic information), and (3) some requirement for subsequent corrective action (whether at inspection stations or garages). Conceivably, some corrective actions could be required without inspection. For example, spark plugs or breaker points could be replaced on the basis of their expected life. Corrective action might also be required on the basis of records kept for the federal new car warranty program. Nevertheless, inspection appears to be a necessary prerequisite to corrective action for in-use vehicles on two counts: (1) to determine what corrective actions need to be taken and (2) to reduce possible underservicing or overservicing. For these reasons, we assume that inspection should be an integral part of any effective program involving maintenance.

On the basis of research performed by TRW Inc., Northrop Corporation, and the State of New Jersey, as well as information from EPA officials, in the Bureau of Mobile Source Pollution Control (see IPA/TRW Report for details of these references), it appears that the most likely initial reduction in aggregate carbon monoxide emissions from an inspection and maintenance program would be on the order of 10 to 25 percent. However, it appears that values in the upper range (particularly 20 to 25 percent) are decidedly less likely than those in the lower range (particularly 10 percent).

It should be stressed that these values represent a definite upper bound for the air pollution control potential of inspection and maintenance, since subsequent deterioration of maintained vehicles (in the interval between inspections) would lessen the effectiveness of this control. For example, assuming an initial reduction of 10 percent and deterioration to original (i.e., pre-maintained) conditions after six months, the aggregate emission reduction, when averaged over a year's period, would amount to only 5 percent. Similarly, if "complete" deterioration occurred after nine months, an annual aggregate emission reduction of only 7.5 percent would be achieved. Actual emission reductions, achievable from inspection and maintenance may also be overstated due to difficulties in (1) obtaining complete compliance from all in-use vehicles owners and (2) securing governmental cooperation in multi-jurisdictional metropolitan areas.

Based on these findings, the strategy was applied as a reduction in CO emissions using values of 5 and 25 percent for illustrative purposes and a value of 10 percent as the most likely reduction. A reduction in hydrocarbon emissions of 12 percent was assumed most likely based on the November 1972 EPA document "Control Strategies for In-Use Vehicles."

2.4.2 Strategy 2: Traffic Flow Controls

Based on the findings in the IPA/TRW report, evaluation of specific city data and the reconnaissance meetings with transportation and other personnel in the cities, traffic flow control strategies were developed for each of the six cities. The data available for each city did not permit, generally, classification into fine-grained geographic areas (e.g., the eight rings used for Washington, D.C.). In view of the fact that the impact of flow controls was based on general experience and judgment, for the purposes of project analysis, the respective cities (except Washington, D.C.) were divided into three broad geographic areas: (1) the CBD or core, (2) an area surrounding the core but still within the political boundaries of the city, and (3) the remaining area outside the boundaries of the city. This three-way division allowed relatively easy division of zones while still permitting our analysis to be somewhat more fine grained than would otherwise be possible.

Using the above classification system, Table 2-2 indicates the speed adjustment factors that were used in each of the six cities. It should be noted that in each city we have assumed implementation of the proposed traffic flow control strategy within a one-year period. This must be considered optimistic in the face of repeated statements by traffic engineers and city administrators that it would take a minimum of two to four years to implement traffic flow control plans -- including computerization, ramp metering, surveillance, and other controls. However, assuming a concerted effort and commitment on the part of each city and the funding available (in time) from the Federal government, a one-year period for implementation might be possible, especially since each of the six cities already has some plans for improved traffic flows, considerable experience, and some staff already available. However, even with these advantages, it is patently clear that the assumption of one year for implementation is still optimistic.

In connection with developing the factors shown in Table 2-2, major emphasis was placed on speed values during the peak hour. However, because eight-hour maximum VMT periods were required for the analysis, the question was raised as to whether to use the same speed change assumptions as for the maximum one-hour period. In this connection, the following assumptions were used based on conversations with traffic engineers in each metropolitan area.

1. It would be expected that speed changes due to improved flow controls would result in substantially lower improvement levels during the off-peak period. The reasons are:
    a. During the off-peak period, the available capacity is not being used and speeds are generally higher than during the peak periods and hence less margin for improvements (or need).
    b. Most improvements in traffic control are aimed at the peak hour and in many cases only marginally spin-off benefits to the off-peak hours. For example, special one-way streets that convert to two ways during the off-peak, special peak-hour light progressions, etc. Thus, the improvements do not help very much during the off-peak periods.

Table 2-2. Speed Adjustment Factors

CITY	Area to Which Speed Factor (%) Below Is To Be Applied			Time Sequence to be Used in Applying Strategy
	Core (CBD)	Remainder of City	Area Outside City Boundary	
Chicago	10%	12%	15%	As in D.C.
Dist. of Columbia	10%	a/	a/	Year 1-0 Year 2-Full Eff. Year 3-0
Denver	5%	5%	5%	As in D.C.
Los Angeles	10%	12%	15%	As in D.C.
New York City	5%	5%	5%	As in D.C.
San Francisco	10%	12%	15%	Year 1-0 Year 2-Full Eff. Year 3-1/2 Eff. Year 4-0

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a/ The following factors were used for Washington, D.C. where data permitted analysis by rings:

Speed Ring -- As Defined by Grid Numbers (mph)	Change in Speed from Base Year (%)				Corresponding Ring Number
	1	2	3	4 to 1977	
10	0	10	-10	0	0
15	0	12	-12	0	1
24.2	0	15	-15	0	2
28.5	0	15	-15	0	3
30	0	15	-15	0	4
45	0	20	-20	0	5-6-7-8

c. The volume of vehicles during the off-peak is usually lower and the average speed higher so improvement percentages are likely to be substantially lower, if anything at all (perhaps with the exception of situations where streets are saturated all the time).

Within this framework, it was therefore considered very unlikely that the percentage changes used for speed improvements for the peak hour would obtain during the off-peak period. In terms of the analysis, the speed change assumptions used for the maximum one-hour were not considered likely to be the same (percentages) as for the eight-hour maximum. In determining, therefore, what percentage speed change to use for the eight-hour maximum, it was necessary to ascertain what percentage of our assumptions of percent change in speed during the peak-hour would hold true for the off-peak hour.

Generally in the six cities in the study, the eight-hour maximum VMT period fully encompassed one of the peak-hour periods and part of another. It was, therefore, quite clear that we could not assume that no speed changes would result from traffic flow improvement for the eight-hour maximum period when in fact the average speed change due to traffic flow controls during the eight-hour maximum would be influenced by the presence of the two (or part of both) peak hours. For example, in Washington, D.C., the maximum eight-hour peak period fell somewhere between the hours of 11 a.m. - 7 p.m. or 12 p.m. - 8 p.m. and included about 50 percent of the 24-hour VMT. Conversations with the traffic engineers indicated that an optimistic assumption is that about 50 percent of the speed improvements would apply for the eight-hour period, and this assumption was used. It is, however, relatively optimistic.

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2.4.3 Strategy 3: Motor Vehicle Restraints

In order to provide for a reasonable motor vehicle restraint strategy, a review of the available data on motor vehicle restraints was undertaken to determine the extent to which evidence was available that would provide some indication of the range of expectations for reductions in VMT. This data review was combined with an evaluation of the specific implementation plans of the six cities, particularly with reference to their own programs for motor vehicle restraints. These implementation plans were also related to the city reconnaissance reports. This section considers each of the latter three elements and presents the assumptions used with respect to the application of a motor vehicle restraint strategy.

- Review of Available Data

A review of data was undertaken as part of the preparation of the IPA/TRW Report. As was noted in that report, there is very little evidence available as to what might be expected in the way of reduction of VMT through the application of motor vehicle restraints. On the basis of the best available data and judgment, and assuming parking controls or some other form of road pricing, the range of reductions in VMT appears to be between 5 and 20 percent. However, 20 percent appears to be the upper limit of any practical action that might be taken within the time frame of the study -- that is by 1977. In Washington, for example, reductions in VMT of 20 percent would probably involve tripling and, perhaps, quadrupling parking rates. The unlikelihood of that level of restraint being implemented has been described in the above cited report.

In addition, VMT reductions of 15 to 20 percent may have to be accompanied by major improvements in public transportation. The cost for these improvements would be substantial and require major appropriations at the Federal level.(7)

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(7) The Final Report, Evaluating Transportation Controls To Reduce Motor Vehicle Emissions in Major Metropolitan Areas, estimates indicated about $14 billion of investment would be required in the six cities for completion of existing public transport plans plus some moderate improvements such as people movers. This level of investment, however, would probably still not be sufficient or include the scope of changes which might be needed.

Data available for the Bay Area Rapid Transit System (BART) in San Francisco provide estimates of the reductions expected in motor vehicle use for 1975. These estimates indicate that in the four counties of Alameda, Contra Costa, San Francisco, and San Mateo the number of trips diverted from motor vehicles to BART by 1975 would reduce the vehicle miles of travel per day by 2.1 percent. In specific important line-haul corridors where transit is more competitive, the diversion factors (for example, Bay Bridge) were as high as 8.1 percent; but in general the estimates ranged below 10 percent (on the average) . They also ranged well below 10 percent if all corridors were taken into account.

Modal split models which predict the percentages of trucks and buses in the vehicle population under varying conditions were examined for Washington, Baltimore, and Minneapolis. These models substantiated the fact that significant changes would be required in parking rates before major diversions in motor vehicle use would occur. In Washington doubling and tripling was implied as it was in Baltimore and Minneapolis. To achieve reductions in motor vehicle use in the range of 20 to 25 percent, implied comprehensive parking control programs with parking space taxes of $60 to $80 a month for all spaces -- private and otherwise -- and elimination of all on-street parking. Only under these severe conditions could one hope to achieve 20 to 25 percent VMT reductions.

From the available evidence and judgment, the conclusion was reached that VMT reductions of over 20 percent are quite unrealistic, at least in the six cities in the study;and by 1977 the reductions in VMT from motor vehicle restraints are likely to be under 20 percent -- probably well under 20 percent.

- Review of Implementation Plans

The limited use of motor vehicle restraints in any form is readily apparent in the Implementation Plans of the six cities. It is only in San Francisco and Los Angeles that any estimates are provided for reductions through motor vehicle restraints. In both cities, a 20-percent reduction is provided; however, these are values estimated by the state and there is no evidence provided that such reductions could be achieved. Furthermore, there is no plan provided as to how such reductions could be achieved or whether it is realistic. For example, the San Francisco plan notes that through public transportation, car pooling, and changes in working schedules, they hope to reduce emissions. They point out, however, "the level of achievement of these measures cannot be closely estimated. The goal, which is set on the optimistic side, is to reduce traffic by 20 percent.(8) Nothing is indicated as to how this 20 percent would be realized or the basis on which it is estimated. In the Los Angeles plan, the same 20 percent is used; and, in fact, the language used to describe the plan is exactly the same as that used for San Francisco with no further evidence.

For the other cities reviewed, the possibilities were unspecified with the exception of Washington, D.C., where a number of limited parking facility proposals are provided (including a ban on on-street parking, sharp increases in commercial parking lot fees, and other potential control devices). In all the cities, there is considerable reluctance to indicate any form of motor vehicle restraint or identify in any specificity its content or the way in which these reductions would be achieved.

- Reconnaissance Trips

Reconnaissance of the six cities substantiated the difficulty of implementing motor vehicle restraints. In fact, with perhaps only minor exceptions, the trend appears to be toward considerable resistance for any kind of motor vehicle restraint. This does not suggest that restraints may not come into effect or that, in time, they may not be accepted. However, within the framework of attempting to achieve emission standards by 1977, there appears to be considerable opposition to be overcome. For example, in San Francisco where a 25-percent parking tax has been in effect on commercial space, we were informed that there had been little or no impact on motor vehicle use with the possible exception of some shift to on-street parking. There has been no change in transit ridership, and there is considerable pressure to remove and/or substantially reduce the parking tax from 25 to 10 percent. There is indication that the proponents of a reduction might be successful.

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(8) San Francisco Implementation Plan, page 61, and Los Angeles Implementation Plan, page 120.

Again, in San Francisco the use of car pool experiments suggests that it is going to be very difficult to achieve even limited goals of diversion (3000 vehicles per day to car pools) and there does not appear to be any overwhelming movement toward supporting motor vehicle restraints in San Francisco.

In New York City restraint on motor vehicle use has been an important element in the city's policy for dealing with congestion, particularly in view of the long history of congestion. A number of vehicle ban proposals have been suggested; however, in general, they have been politically unacceptable. For example, efforts to develop a Madison Avenue Mall have been generally deterred and it appears likely that only limited implementation of the Mall will occur.

In Los Angeles the need for regional controls in order to solve the pollution problem (as described in the Interim Report) indicates that reductions of 20 percent VMT would have to be undertaken throughout the area since reductions in the CBD alone would not be particularly helpful. The uniformity of the distribution of the emissions and the difficulty of implementing them in the Los Angeles area(given the multiplicity of governments and the general importance of the automobile in the daily traffic movements) suggests extraordinary difficulty in implementing any kind of major restraint effort.

In Washington, D.C., it was proposed to provide an all-day parking tax of $1 a day to be implemented as part of the effort to reduce VMT. Estimates ranged from 8 to 16 percent reduction in trips; overall reductions in the range of four percent. Major opposition resulted in postponement of the issue to 1973; and again it appears very unlikely that even a small tax of a dollar a day (which would not, perhaps, result in more than a 4 to 5 percent reduction) will be passed, if at all, before 1974

The Chicago Plan indicated that no motor vehicle restraints were contemplated with emphasis being placed upon the automobile manufacturers providing the necessary reduction through changes in engine design and/or control devices and improvements in traffic flow controls. Reconnaissance made it quite clear that there was opposition on the part of the city government to any policy of motor vehicle restraint.

Finally, in Denver indications are that only small reductions may be expected from any kind of motor vehicle restraint program. The city is opposed to any kind of motor vehicle restraint; the administration has no present plans for motor vehicle controls and does not intend to implement any. We were advised that the automobile is an important and basic element in the life of residents in the City of Denver and that no one anticipates any major restraints.

- Summary

In view of the reconnaissance experience, the review implementation plans and the findings of the IPA/TRW Report and other evidence reviewed, the following conclusions appear relevant:

1. It would appear at the present time that it is not politically feasible to achieve any major program of motor vehicle restraint in any of the six cities under review. Though minor programs could emerge in the way of price increases for parking, no significant impact is likely to have any major effect by 1975 and only slightly more for 1977.
2. The reductions of 5 to 20 percent indicated in the Interim Report, though within the realm of possibility, must be considered to represent broad ranges. For the six cities under review and based upon an evaluation of opinion in the cities and the other elements described, 20 percent appears to be in the very upper limits of what is even realistically feasible and seems to be a very unlikely possibility for any of the six cities.

- Assumptions

Within the context of the difficulties described above, the following assumptions were made with respect to the potential for reductions in VMT through the use of a motor vehicle restraint strategy:

1. A motor vehicle restraint strategy will have to be accompanied by very substantial improvements in transit involving fairly substantial sums of investment.
2. The most feasible restraint appears to be some form of pricing policy -- perhaps increases in parking costs, possibly toll roads or some other forms of road pricing. This appears more feasible because of the somewhat more subtle characteristics of the impact so that public opposition to the motor vehicle restraint (particularly from motor vehicle owners) might be somewhat less. Major vehicle bans and frontal assaults of a similar nature are likely to encounter fierce opposition.
3. Of all the range of possibilities, all assumptions about reductions of VMT must be considered optimistic in the light of a target of 1977. For purposes of testing a motor vehicle strategy, the following ranges were used:

Range of Reductions in VMT From
Motor Vehicle Restraints
Six Cities Study

1. Moderately optimistic - 5 percent
2. Optimistic - 10 percent
3. Very optimistic - 15 percent

After careful consideration of all of the evidence and recognizing that a considerable amount of judgment is involved, it was decided that none of the six cities are likely to achieve even 15 percent reductions by 1977. It was also assumed that motor vehicle restraints are likely to have some positive impact on traffic flow controls through their reductions in the volume of traffic by retarding or slowing down the extent to which traffic flow improvements are used up by generated traffic.

In the context of the previous discussion, Table 2-3 summarizes the Strategy 3 factors which were applied, including the effect that might be considered with respect to traffic flow controls. The traffic flow control impact of a motor vehicle restraint strategy was based on estimated annual traffic growth (largely) in the CBD areas of the respective six cities.

- Analytical Application of Strategy 3

Strategy 3 was applied to the 1977 data base as a combination of traffic restraints, traffic flow control, and a reduction in CO and hydrocarbons due to the inspection and maintenance program. This combined strategy assumes for the purpose of analysis that the full impact of each control element will be achieved during 1977. The application procedure does not allow the impact of motor vehicle restraints on traffic flow to be displayed on Table 2-3. Since the analysis is performed for a specific year (1977), the retarding impact of motor vehicle restraints in holding back generated traffic resulting from speed improvements are not taken into account

Table 2-3. Motor Vehicle Restraint Factors

A: OFFSET TO TRAFFIC GROWTH

City	Estimated Growth Rate (in CBD)	Years to Offset Growth in Traffic with VMT Reduction of 5%	10%	15%
Washington, D.C.	5%	1	2	3
Chicago	2	3	5	7
New York City	3	2	3	4
Denver	5	1	2	3
San Francisco	2	3	5	7
Los Angeles	4	1	3	4

B: STRATEGY III FACTORS

City	Motor Vehicle Restraint in VMT	Impact Period:Year						Years Before Traffi Flows Offset: Year					
		0	1	2	3	4	5		1	2	3	4	5
Denver	5%	(Base Year)	(Implement Yr.)	-5%----------▷				Imp.	---▷				
Washington, D.C.	10	"	"	-10%----------▷				"	-------▷				
New York City	10	"	"	-10%----------▷				"	----------▷				
Chicago	5	"	"	-5%----------▷				"	----------▷				
San Francisco	10	"	"	-10%----------▷				"	------------▷				
Los Angeles	5	"	"	-5%----------▷				"	---▷				

3.0 SIX CITY TRANSPORTATION STUDY RESULTS

3.1 INTRODUCTION

The methodology developed for the evaluation of the impact of transportation controls on air quality was applied to six major metropolitan areas including: Chicago, New York, Denver, San Francisco, Los Angeles, and Washington, D.C. Three transportation control conditions were considered for analysis as follows:

(1) current conditions - as close to existing conditions as transportation data will allow,
(2) projected transportation conditions for 1977 assuming 1975 automotive emissions standards are met, and
(3) projected conditions for 1977 with estimates of the effects of several transportation controls.

The particular controls evaluated were selected as described in Section 2.4 of this report. Although many potential controls were considered, only three were selected for air quality impact calculations due to project and data constraints. These were:

- Strategy 1 - Inspection and Maintenance

  The strategy was applied as a 10 percent reduction in CO emissions and a 12 percent reduction in Hydrocarbon emissions.

- Strategy 2 - Traffic Flow Controls

  Average vehicle speeds were increased by the percentages given in Table 2-1 to indicate the impact of this strategy.

- Strategy 3 - Combined Strategies

  The impact of Strategies 1 and 2 were combined with a VMT reduction due to vehicle restraints as shown in Table 2-2. (Vehicle restraints and resultant VMT reductions used were those considered most likely to occur by 1977.)

3.2 METROPOLITAN AREA ANALYSIS - CHICAGO

3.2.1 Data Base and Methodology

3.2.1.1 Transportation Data

- Basic Data

Basic data were provided by the Chicago Area Transportation Study (CATS) and consisted of VMT and speed data by zone for peak and off-peak periods for 1968/69 and projections to 1985.

Specifically, the project was supplied with computer printouts showing volume and speed for the 1900 districts comprising the Chicago region. The project was also provided with material on traffic counts and other data from the traffic departments of both the State of Illinois and the City of Chicago. The characteristics of the two networks (base year and projected) are as follows:

Highway Network

Assignment 901: is the 1968/1969 eight-county highway network.

Assignment 903: is the 1968/1969 network with major highway improvements presently under construction or improvements to be initiated in the near future.

According to CATS, the trips used in the simulation and the trip lengths used to calibrate CATS distribution model are from five different sources.

1. For the area inside CATS 1956 cordon line (approximately Cook County), Assignment 901 uses information developed by a major update of CATS 1956 survey done in 1965 and Assignment 903 uses estimates for 1980 developed from this update.

2. For the area outside the 1956 cordon line in Illinois, both assignments use information from three smaller studies done in the region. Assignment 901 uses data from surveys taken during 1966-1969, and Assignment 903 uses 1985 estimates made from these surveys.

3. For Indiana, both assignments use information provided by Lake-Porter Counties Regional Transportation and Planning Commission. Assignment 901 uses a 1968-1969 estimate and Assignment 903 uses a 1985 estimate.

- Interpolation Factors

In interpolating 1985 VMT projections to 1977, population, employment and land-use data were used.(1) Factors were developed for interpolating for each township and used to estimate zonal values for 1977. The projected 1977 VMT is the 1968 VMT, plus the township factor multiplied by the difference in 1985 VMT projections.

e.g.: $1977 VMT_{ij} = 1968\ VMT_{ij} + Factor_i\ (1985\ VMT_{ij} - 1968\ VMT_{ij})$

where i = township

j = zone within township.

The annual percent projected increase in population from 1965 to 1975 and from 1975 to 1985 were obtained. These percentage figures were used to determine the estimated ratio of growth from 1968 to 1977 compared to the period 1968 to 1985.

- Estimates of Eight- and Peak-Hour VMT

In Chicago, peak-hour speed and VMT data were available directly from the assignment model. However, estimates had to be made for the eight-hour period of maximum VMT.

The calculation of this eight-hour peak was based on two sources:

a. The Bureau of Street Traffic, Traffic Volume Factors for Preferential Street System of Chicago, (Revised, October 1968). Counts were taken at 40 locations distributed throughout Chicago in late 1966, '67 and '68. Page 4 of the study "Average Distributions of Traffic Volumes by Hour on the City of Chicago Preferential Streets" indicated the (two-way) percentages of cars by hour for the 40 streets. A quick tabulation indicated that the maximum was 47.4 percent between the hours of 12 noon and 8 p.m.

b. The Bureau of Street Traffic, Cordon Count: Central Business District, 1971, Table II (p. 34), "Comparison by Fifteen Minute Periods of Vehicles Entering and Leaving the CBD of Chicago -- Bounded by Roosevelt Road, Lake Michigan and the River." Running eight-hour totals were obtained; these

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(1) The township adjustment factors were determined through interpolation of population projections provided in Northeastern Illinois Planning Commission "Metropolitan Planning Paper No. 10: Population, Employment and Land Use Forecasts for Counties and Townships in Northeastern Illinois" Chicago: September 1968 (mimeo).

> indicate the maximum vehicle count occurred in the period 10:15 a.m. to 6:15 p.m. Since the count was conducted only between 7 a.m. and 7 p.m., eight-hour maximum VMT cannot be established as a percent of 24-hour VMT.

Based on these sources for Chicago, the eight-hour maximum VMT was approximately 48 percent of the 24-hour average weekday VMT. The maximum eight-hour period varied in different parts of the city: In the CBD, it appeared to be from 10:15 a.m. to 6:15 p.m., while for the city as a whole, it appears to be from 12 noon to 8 p.m.

3.2.1.2 Meteorological Data

Seasonal average wind speeds and directions were obtained from National Climatological data charts. It should be noted that these averages represent typical cases for the area and are applied only to give representative samples of the possible dispersion patterns for the area.

3.2.1.3 Stationary Sources

No detailed stationary source data were available for Chicago. EPA supplied estimates of the precentage of total emissions due to stationary sources within the region. These percentages were applied to the calculated mobile source emissions to obtain an estimate of the total emissions per grid. Estimates of the impact of projected stationary source controls were supplied by the Department of Environmental Control. The most significant change is a 20-percent reduction in total hydrocarbon emissions expected by 1977.

3.2.2 Summary of Results

The following discussion presents the impact of the transportation controls on each of the three pollutants considered. Figure Chi.1 shows the analysis area.

3.2.2.1 Carbon Monoxide

Table Chi.1 summarizes the maximum emissions and maximum concentrations predicted for carbon monoxide for each of the applied control strategies and the uncontrolled cases. The maximum concentrations predicted are given for the "worst case" which is defined by a wind speed of 2.5 meters/second. The areas of maximum CO emissions and concentrations are all associated with major intersections along the JFK Expressway. (See Figure Chi.2.) The grid of absolute maximum emissions or concentrations varies from case to case due to the effects of the detailed data supplied. (See Section 3.2.1.)

Stationary sources are treated as background emissions as described in Section 3.2.1.3 due to lack of detailed source data. This procedure would tend to understate the effect of a large stationary source in an area of low vehicular emissions and to overestimate the stationary emissions in an area of high vehicular emissions. For CO emissions, the deviation from realistic conditions is minimal because mobile sources represent approximately 96 percent of the total CO emissions for the Chicago region. The impact of this procedure on the dispersion patterns is to make them more representative of mobile sources. This may be helpful in visually comparing the effect of individual strategies on the base year patterns.

The 1977 predictions show the effect of emission control devices only on the maximum eight-hour and peak-hour concentrations. The 1968 maximum emissions would be reduced by nearly three quarters bringing the predicted 1977 concentrations below federal standards. Maintenance of this level of reduction is dependent upon the deterioration of the control device efficiency as explained in Section 2.4. An inspection and maintenance program would maintain this level of reduction and reduce mobile source CO emissions an additional 10 percent as shown in Strategy 1.

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1968	30582 (917)*	28748 (917)	32.5 (917)	58.8 (917)
1977	9853 (821)	8362 (821)	8.9 (821)	15.9 (821)
Strategy 1	9019 (821)	7528 (821)	8.1 (821)	14.5 (821)
Strategy 2	9443 (821)	7952 (821)	8.5 (884)	15.0 (1010)
Strategy 3	8292 (821)	6801 (821)	7.4 (821)	13.0 (821)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1968	2095 (821)	1362 (821)	1800 (821)	2200 (821)
1977	1405 (821)	735 (338)	1100 (821)	1400 (821)
Strategy 3	1371 (821)	638 (821)	1100 (821)	1300 (821)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures Chi.2, Chi.3, and Chi.4 for location of these maxima for CO, HC, and NO_x, respectively.

Table Chi.1. Predicted Maximum Emissions and Concentrations

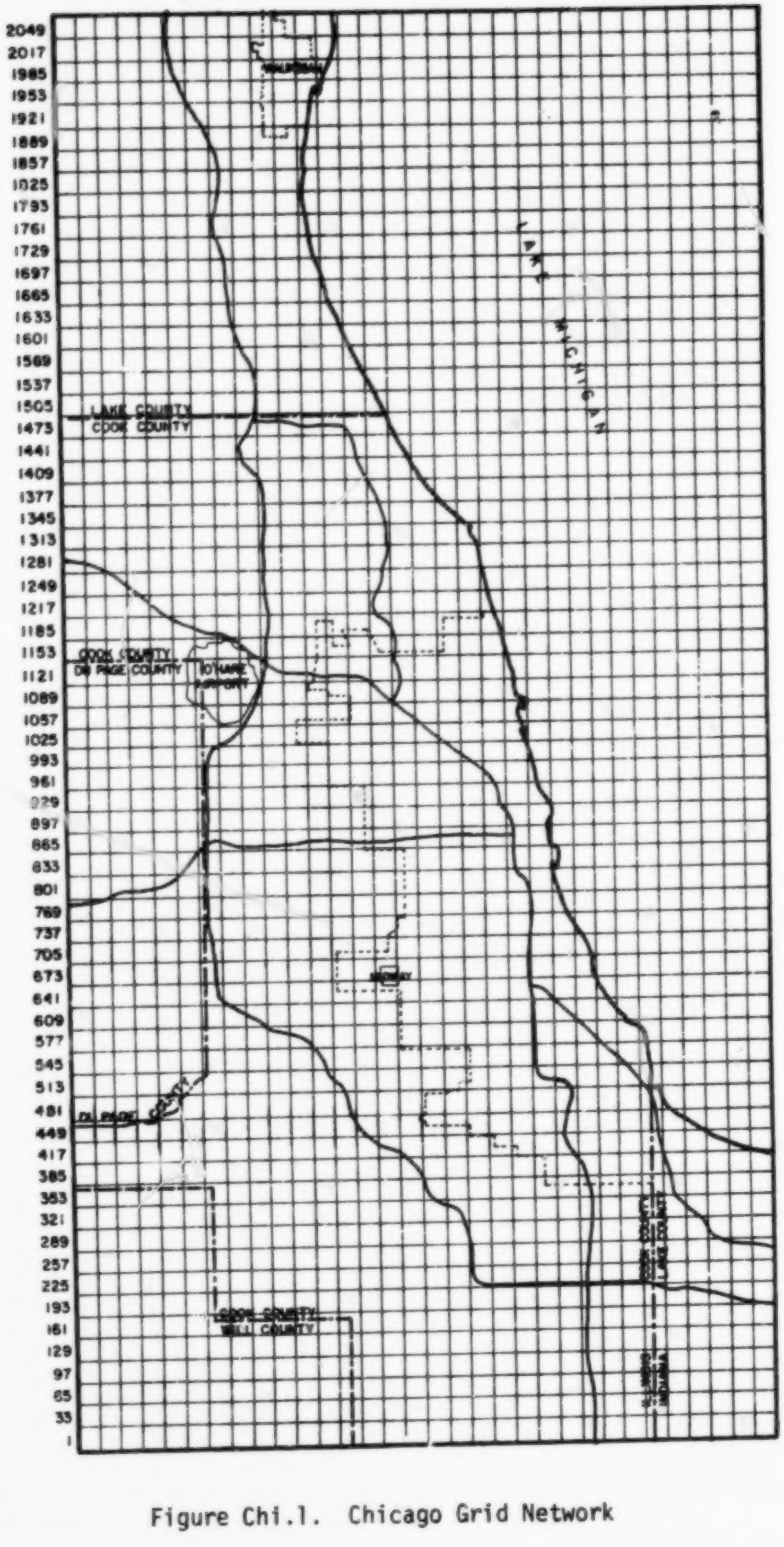
2049
2017
1985
1953
1921
1889
1857
1825
1793
1761
1729
1697
1665
1633
1601
1569
1537
1505
1473
1441
1409
1377
1345
1313
1281
1249
1217
1185
1153
1121
1089
1057
1025
993
961
929
897
865
833
801
769
737
705
673
641
609
577
545
513
481
449
417
385
353
321
289
257
225
193
161
129
97
65
33
1
WAUKEGAN
LAKE MICHIGAN
LAKE COUNTY
COOK COUNTY
COOK COUNTY
DU PAGE COUNTY
O'HARE AIRPORT
MIDWAY
DU PAGE COUNTY
COOK COUNTY
WILL COUNTY

Figure Chi.1. Chicago Grid Network

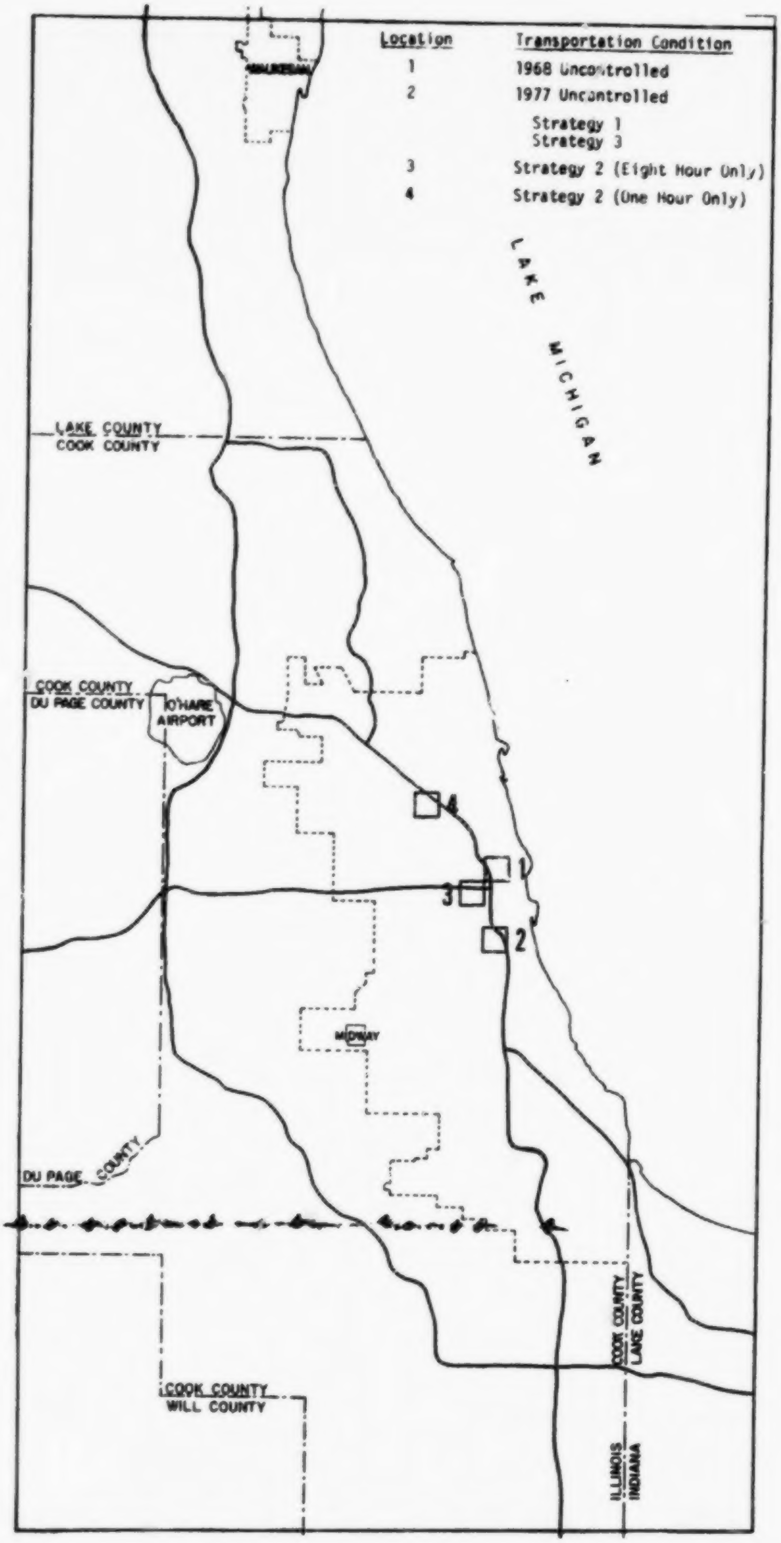
Location
Transportation Condition
1
1968 Uncontrolled
2
1977 Uncontrolled
Strategy 1
Strategy 3
3
Strategy 2 (Eight Hour Only)
4
Strategy 2 (One Hour Only)
WAUKEGAN
LAKE MICHIGAN
LAKE COUNTY
COOK COUNTY
COOK COUNTY
DU PAGE COUNTY
O'HARE AIRPORT
4
1
3
2
MIDWAY
DU PAGE COUNTY
COOK COUNTY
WILL COUNTY
COOK COUNTY
LAKE COUNTY
ILLINOIS
INDIANA

Figure Chi.2. Maximum CO Concentration Locations for Each Transportation Condition Given in Table Chi.1

Strategy 2 (Traffic Flow Control) would, in effect, increase the traffic speeds in the central areas. This would slightly decrease CO emissions; however, the additional impact on concentration values would be minimal without additional traffic controls, even this 5 percent decrease in emissions would probably disappear within one year due to induced traffic volume increases.

Strategy 3 (Combined Strategies) shows the result of combining traffic flow controls (Strategy 2), vehicle restraints (5 percent VMT reduction), and inspection and maintenance (10 percent CO emission reduction). The prediction assumes full benefit of all strategy elements would be achieved in 1977. The predicted mobile source emissions show approximately 20 percent decrease from 1977 uncontrolled estimates. The resulting eight-hour maximum concentration is well below the federal standard.

Table Chi.2 summarizes the annual emission totals for each pollutant for the entire grid area for each transportation control condition. These values can be used for "rollback" calculations for the Chicago area.

3.2.2.2 Hydrocarbons

Table Chi.3 summarizes the maximum emissions and concentrations for hydrocarbons in the grid area. Figure Chi.3 shows the location of these maxima. Note that peak-hour concentrations are calculated as opposed to federal standards for the three-hour (6 - 9 a.m.) time period. Transportation did not permit computation of concentration corresponding to the standard time periods. These values have been adjusted to three-hour averages using Larsen's model(2) and ambient data.

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(2) R. I. Larsen, "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards," November 1971, Office of Air Programs Publication No. AP-89.

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1968	3880155	3647420	691634	560204	295729	192254
1977 (uncontrolled)	1649731	1412249	279902	174758	226647	119861
Strategy 1	1504713	1271585	258931	153787	NA	NA
Strategy 2	1575066	1341973	272682	167538	NA	NA
Strategy 3	1381365	1148202	243556	138412	215466	111709

Table Chi. 2. Annual Emissions (tons/year) for the Area Shown in Figure Chi. 1.

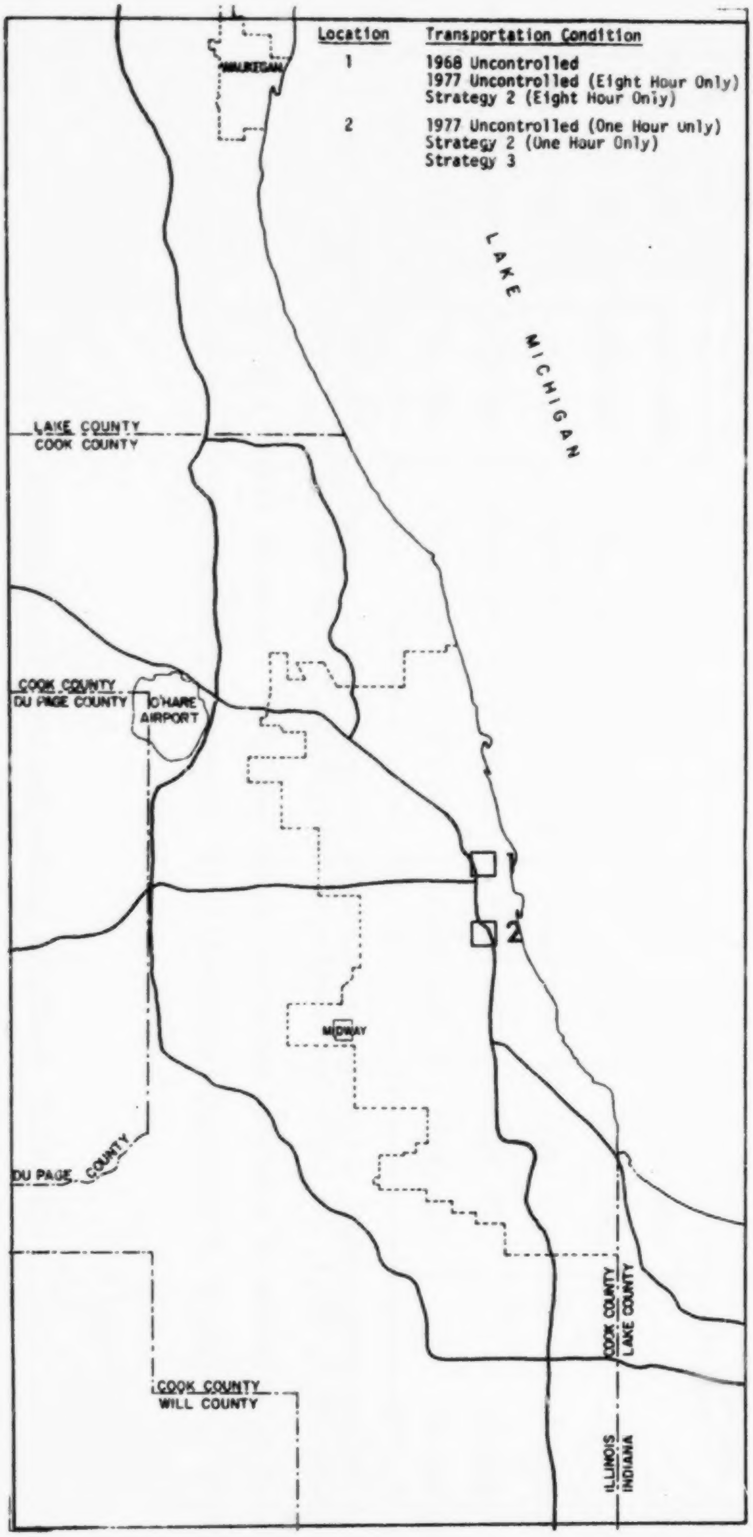
HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1968	4929 (917)[1]	3992 (917)	5100 (917)	8300 (917)	5200 (917)	6700 (917)
1977	1896 (821)	1026 (821)	1500 (917)	2300 (821)	1500 (917)	1800 (821)
Strategy 1	1773 (821)	903 (821)	1000 (917)	1500 (821)	1000 (917)	1200 (821)
Strategy 2	1859 (821)	989 (821)	1500 (917)	2200 (821)	1500 (917)	1800 (821)
Strategy 3	1686 (821)	816 (821)	400 (821)	600 (821)	400 (821)	500 (821)

[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures Chi.2, Chi.3, and Chi.4 for location of these maxima for CO, HC, and NO_x, respectively.

[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table Chi.3. Predicted Maximum Emissions and Concentrations


WAUKEGAN
LAKE MICHIGAN
LAKE COUNTY
COOK COUNTY
COOK COUNTY
DU PAGE COUNTY
O'HARE AIRPORT
1
2
MIDWAY
DU PAGE COUNTY
COOK COUNTY
WILL COUNTY
COOK COUNTY
LAKE COUNTY
ILLINOIS
INDIANA

Location	Transportation Condition
1	1968 Uncontrolled 1977 Uncontrolled (Eight Hour Only) Strategy 2 (Eight Hour Only)
2	1977 Uncontrolled (One Hour Only) Strategy 2 (One Hour Only) Strategy 3

Figure Chi.3. Maximum HC Concentration Locations for Each Transportation Condition Given in Table Chi.1

Hydrocarbon concentrations and emissions are affected by stationary source emissions to a greater extent than CO concentrations as can be seen in Table Chi. 3. Again, the treatment of stationary sources as a background tends to minimize the possible impact of large stationary sources and possibly overstate the contribution from stationary sources in many outlying areas containing major transportation arteries. It may therefore be more appropriate to consider the relative reduction in mobile source emissions rather than resultant concentrations for the purpose of analyzing the impact of transportation controls.

The 1977 uncontrolled mobile emissions show a reduction of approximately 73 percent over 1968 emissions for hydrocarbons. This reduction due to internal automotive controls only may be sufficient to meet federal standards if the major stationary sources are controlled. Since some stationary sources controls are expected to be in effect by 1977 in Chicago, the federal standard should be met; however, the predicted concentrations do not support this. An inspection and maintenance program could be expected to maintain the reductions achieved by new car standards and to give an additional 12 percent reduction in hydrocarbon mobile source emissions as shown by Strategy 1.

Traffic flow control (Strategy 2) would reduce the maximum 1977 emissions by less than 5 percent, and applied alone this strategy would have very little lasting impact on concentrations. However, in combination with some form of vehicle restraints (Strategy 3), an additional 8 to 10 percent reduction in hydrocarbon emissions from mobile sources could be realized.

3.2.2.3 Oxides of Nitrogen

Table Chi.1 summarizes the maximum concentrations and emissions for NO_x in the grid area. Figure Chi.4 shows the location of these maxima for each transportation control condition. It can be seen from the table that the predicted maximum concentrations are grossly affected by stationary sources for which no control is expected by 1977. For the purpose of analyzing the impact of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than resultant concentrations.

The 1977 uncontrolled mobile emissions show approximately 45 percent reduction over 1968 emissions. Whether this reduction value would be sufficient to bring actual air quality within federal guidelines is not clear from the predicted values.

Strategy 3 (Combined Emission and Traffic Controls) is the only transportation control strategy with a direct impact on NO_x emissions. The approximately 15 percent decrease in NO_x emissions over 1977 uncontrolled emissions is a result of reduced VMT due to vehicle restraints.

Table Chi.2 lists the predicted annual emissions for NO_x for the entire grid network for each transportation control condition. Both total emissions and mobile source emissions are given. The annual emissions from this table can be used for "rollback" calculations.

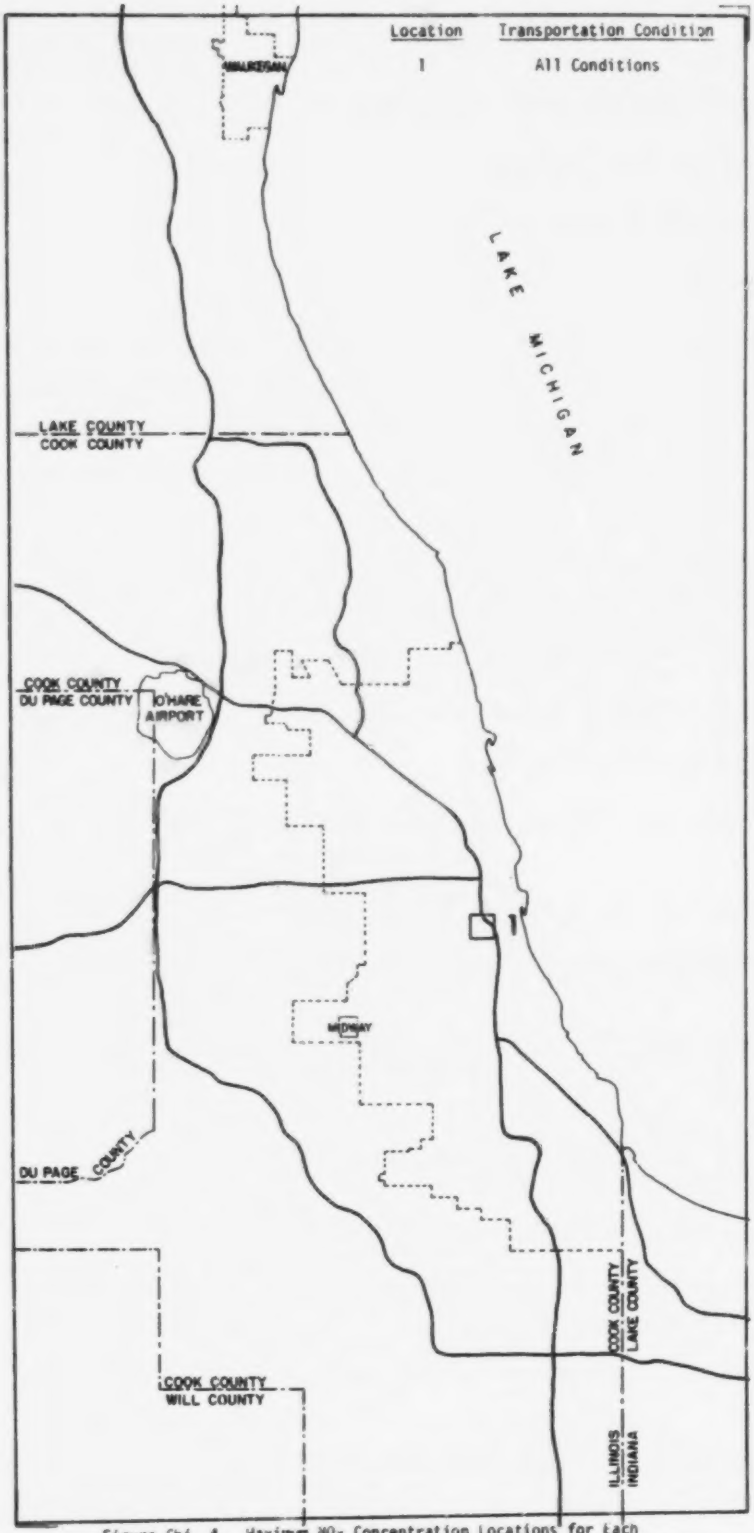

Location
Transportation Condition
1
All Conditions
WAUKEGAN
LAKE MICHIGAN
LAKE COUNTY
COOK COUNTY
COOK COUNTY
DU PAGE COUNTY
O'HARE AIRPORT
1
MIDWAY
DU PAGE COUNTY
COOK COUNTY
LAKE COUNTY
COOK COUNTY
WILL COUNTY
ILLINOIS
INDIANA

Figure Chi. 4. Maximum NOx Concentration Locations for Each Transportation Condition given in Table Chi.1.

Figure Chi. 4. Maximum NOx Concentration Locations for Each Transportation Condition Given in Table Chi.1.

3.3 METROPOLITAN AREA ANALYSIS - NEW YORK

3.3.1 Data Base and Methodology

3.3.1.1 Transportation Data

- Basic Data

Basic data were provided by a number of cooperating agencies, especially the Tri-State Regional Planning Commission, The Transportation Planning Division of the New York City Planning Commission and the Port of New York Authority. Specifically, the following key items were obtained from the Tri-State Transportation Commission:

a. Vehicle miles traveled for 1970-1977 for each of 127 analysis areas
    (1) By type of roadway
    (2) Average operating speeds
    (3) Estimated speeds for 1977
    (4) Average volume per lane

b. Vehicle registrations

c. Model for highway needs evaluation

d. Hourly vehicular traffic by type.

e. Flow and volume maps of the region.

The New York City Planning Commission provided the following additional inputs:

a. Traffic Department vehicle counts from the Annual Cordon Survey for 1965-1971.

b. Tunnel and river counts for 1965-1971.

c. Twenty-four hour counts by one-hour sequences for major corridors.

d. Vehicle population for New York City, 1965-1971.

- Disaggregation of New York City Data

As noted elsewhere in this report, the analysis focused on the CBD peak-hour traffic. In New York City, the initial VMT data provided information classified into only three "Analysis Areas" for all of the Borough of Manhattan.

These relatively large Analysis Areas' 1977 VMT did not provide consistent emission results -- e.g., New York City for 1970 calculations fell below Federal standards. In order to develop data which would more accurately reflect variations in the concentration of VMT, Tri-State provided 1963 VMT data broken down into square mile units. This provided a basis for disaggregating the three Analysis Areas covering Manhattan into approximately 30 areas. Similar disaggregations were possible for the other Analysis Areas including Manhattan, Bronx, Brooklyn, Queens, and Richmond Counties in New York and Hudson and Bergen Counties in New Jersey.

Calculation of Manhattan VMT based on these revised square mile data indicated a total of 5,668,820 VMT in 1963 (based on 1964-1965 24-hour weekday traffic counts). This compared to 6,035,850 VMT for 1970 and 6,402,877 VMT for 1977 projections shown by the Tri-State printouts. Conversations with Tri-State indicated that the 1963 square mile VMT of 5.67 million was consistent with their 1970 and 1977 forecasts for Manhattan and were advised that no adjustments would be required in the VMT printouts for 1970 and 1977.

A final step in the disaggregation process involved the distribution of 1970 and 1977 VMT into a square mile distribution. Because no square mile data were available to the project for the period after 1963, both 1970 and 1977 VMT were distributed on the same percentage basis as the 1963 VMT square mile data. Though this introduced error in the distribution of VMT for both 1970 and 1977, we were advised by Tri-State that the error was relatively small -- e.g., the relative VMT was not substantially different between 1963 and 1970. Unfortunately, the errors introduced had to be accepted since no alternative data were available and all analysis for New York would have had to be eliminated. However, it is quite obvious that land uses have changed in Manhattan since 1963 and some differences in VMT distributions have undoubtedly occurred.

The specific methodology used is enumerated below:

1. The percentage distribution of VMT by square mile was calculated for each Analysis Area to be included in our model. This included a 20-mile square region covering New York and New Jersey.

2. The percentage contribution of each square mile to the total VMT in each Analysis Area was calculated for 1963 and then applied to 1970 and 1977 VMT for each Analysis Area.

3. The use of 1963 VMT percentage distributions per square mile for 1970 VMT clearly does not incorporate changes in land uses and trip-making since 1963. The application of 1963 square mile distributions to 1977 data, of course, further compounds the error. However, the error will be somewhat confined in view of the fact that the VMT projections by Analysis Areas for 1970 and 1977 themselves take into account the shifts in land use and travel. (For example, the Analysis Areas comprising Richmond show substantial growth in relation to the Manhattan Analysis Areas between 1970 and 1977.) In Analysis Areas 4 through 7 (The Bronx), VMT between 1970 and 1977 increased by about 4.51 percent (from 5.45 to 5.70 million). This total is disaggregated (by Tri-State) into each of the separate Analysis Areas 4 through 7 and each Analysis Area has a different rate of growth (reflecting the difference in the projected travel expected). The VMT for 1970 and 1977 may be considered reliable in that they reflected the assumptions and conclusions postulated by the regional transportation planning agency.

   New error is introduced when the 1963 percentage distributions of VMT per square mile are applied to each of the Analysis Areas. However, without data on changes in land use, floor space or some other variable related to trip-making, there was no way to correct the error.

- Estimation of VMT by Vehicle Type: 1977

Because of the importance of trucks in New York City VMT, estimates of the split between light and heavy duty vehicle VMT was made. The procedure used is described below:

1. Total 1963 VMT for each borough was obtained from the NYC Draft Air Pollution Plan (NYAP). (These VMT had been obtained by New York City from the Tri-State Regional Planning Commission Report, Streets and Highways: A Regional Report, January 1966.)

   a. Bus data was obtained from NYAP which calculated diesel (D) and gasoline (G) bus mileages on the basis of data from the Transit Authority.

   b. Fleet medallion, non-fleet medallion, and non-medallion cab mileages were calculated by NYAP on the basis of discussions with the Taxi Commission.

   c. Truck mileage was calculated from figures provided by the Tri-State Commission. Airline mileage was multiplied by 1.25 to provide an estimate of actual mileage. For the Manhattan breakdown, it was assumed that NYAP percentage distribution held -- e.g., that 84.1 percent of all Manhattan truck mileage took place in Analysis Area 001. It is also assumed by NYAP that one-sixth of truck mileage is diesel (D) and the rest is gasoline (G).

   d. Automobile mileage was calculated as a residual.

2. 1970 VMT was projected from the 1963 VMT estimates as follows:

   a. Total 1970 VMT, bus VMT and truck VMT were projected by the same ratio (for each borough) as the increase in bridge and tunnel crossings computed by NYAP. (Note: The NYAP adjusted downward the Richmond [Staten Island] increase, and this adjustment was accepted.)

   b. Taxi mileage was assumed to remain unchanged.

   c. Automobile mileage was calculated as a residual.

   d. The vehicle split was obtained for each borough by calculating the percent mileage for each vehicle type.

3. 1977 VMT was projected from the 1963 and 1970 VMT estimates as follows:

   a. Total 1977 VMT, bus, taxi, truck, and auto VMT were projected from 1970 VMT estimates by the 1963 to 1970 VMT ratio.

   b. The vehicle split was obtained for each borough by calculating the percent mileage for each vehicle type.

- Speed Factors

Though the New York City data on speed provided by the Tri-State Regional Planning Commission were appropriate for average speed during the eight-hour maximum VMT period, they were not considered applicable for the one-hour peak VMT period. Based on journey-to-work data from the 1963 Home Interview Survey, the Tri-State Regional Planning Commission developed a series of relationships for travel to the Manhattan CBD. Specifically, four modes were selected: auto driver, railroad, subway and commercial bus. The inbound peak period was set as 7 a.m. to 9:59 a.m. -- these three hours comprising 84 percent of the journey-to-work travel. The remaining 21 hours of the day were defined as the off-peak period.

Using the findings of the Tri-State analysis, it was possible to develop speed zones similar to those used in the Washington, D. C., analysis. These peak-hour speeds were expressed in miles-per-hour and were related to trip distance with trip distance measured in airline miles and time expressed on a door-to-door basis including walking. Though some error exists in time estimates (since there may be some walking distances after arrival at work that would result in somewhat longer time of travel), these are not considered to be significant for purposes of the analysis. Based on our analysis, the following speed adjustment factors were applied to appropriate analysis areas as related to distance from the CBD:

Table 3.3-1. Speed Adjustment Factors for the New York Region by Distance From CBD

Distance Segment	Ratio of Peak Hour Speed to Off-Peak Hour Speed
1	50%
2	67
3	75
4	78
5	79
6	80
7	80
8	81
9	82
10	83
11	84
12	85
13	85
14	85
15	86
16	87
17	88
18	89
19	90
20	91
24	92

- Peak-Hour and Eight-Hour Maximum VMT Periods

Base major bridge and tunnel crossings hourly data were analyzed to estimate the peak one- and eight-hour periods of VMT. From these analyses it was estimated that the eight-hour peak VMT period accounts for 46.3 percent of the 24-hour VMT; the one-hour peak accounted for 7.8 percent of the 24-hour total VMT. These factors were used in developing the one- and eight-hour data for analysis zones in New York City.

3.3.1.2 Meteorological Data

National climatological charts were used to obtain seasonal averages for wind speed and direction. It should be noted that these averages are used to represent typical cases for the area and are applied only to give representative samples of the possible dispersion patterns for the area.

3.3.1.3 Stationary Sources

County data were available for New York giving the 1970 and 1977 emissions for each pollutant due to stationary sources. These county totals were apportioned to the grid areas using the VMT for each grid as an apportioning factor.

3.3.2 Summary of Results

The following discussion presents the impact of the transportation controls on each of the three pollutants considered. Figure N.Y.1 shows the analysis area.

3.3.2.1 Carbon Monoxide

Table N.Y.1 summarizes the maximum emissions and maximum concentrations predicted for carbon monoxide for each of the applied control strategies and the uncontrolled cases. The maximum CO concentrations shown in the table are associated with major expressway and tunnel areas near the tip of Manhattan. Other areas of high concentration include two areas on the New Jersey shore both associated with major expressway or tunnel intersections, Central Manhattan, and a strip between the Bronx and Queens which appears to be a result of the expressway system connecting the two airports.

Stationary source data in New York were given on a county basis and were distributed among the individual grids using VMT per grid as the apportioning factor. By applying these stationary source emissions as a background varying with vehicular emissions, the mobile source emission distribution pattern is retained and predicted concentration values should be more realistic. The maximum concentration values given in Table N.Y.1 indicate that current eight-hour values are above the federal standards. The projected 1977 values for these same time periods suggest that the peak-hour values will be easily controlled by the direct application of automotive control devices. Maximum eight-hour values are predicted to be below the federal standard for the "worst case" considered.

The projected 1977 mobile source emissions could be reduced by approximately 10 percent by the introduction of an inspection and maintenance program (Strategy 1) in the metropolitan area. This program would also insure the reduction achieved by new car standards are not deteriorated.

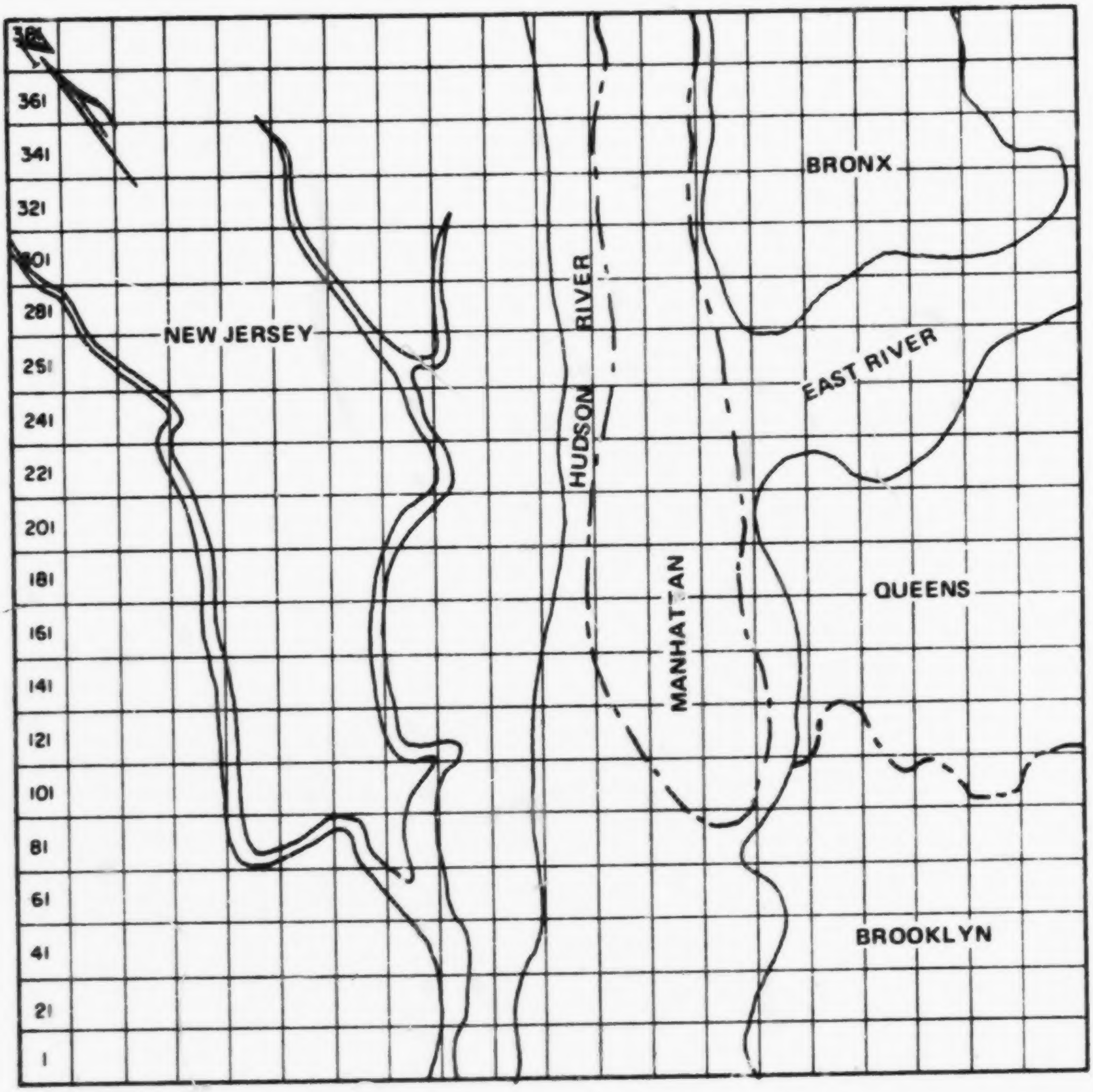

381
361
341
321
301
281
261
241
221
201
181
161
141
121
101
81
61
41
21
1
NEW JERSEY
HUDSON RIVER
MANHATTAN
BRONX
EAST RIVER
QUEENS
BROOKLYN

Figure N.Y.1 New York Grid Network

Total Area - 400 mi^2

Grid Area - 1 mi^2

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1970	20244 (134)*	19425 (134)	19.9 (134)	32.2 (134)
1977	7388 (134)	7192 (134)	7.4 (134)	11.7 (134)
Strategy 1	6671 (134)	6475 (134)	6.7 (134)	10.6 (134)
Strategy 2	7301 (134)	7105 (134)	7.3 (134)	11.6 (134)
Strategy 3	5953 (134)	5757 (134)	6.0 (134)	9.4 (134)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (µg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1970	9064 (134)	2622 (134)	6800 (134)	7500 (134)
1977	4898 (134)	1880 (134)	3800 (134)	4400 (134)
Strategy 3	4710 (134)	1692 (134)	3700 (134)	4200 (134)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure N.Y.2 for location of these maxima for CO, HC, and NO$_x$, respectively.

Table N.Y.1. Predicted Maximum Emissions and Concentrations

Strategy 2 (Traffic Flow Controls) appears to be slightly effective for the New York area. The slight improvement in mobile emissions can be attributed to the increased average vehicle speed implied by this strategy. If this strategy is applied without further vehicle restraints, however, any improvement in emissions may be quickly degenerated by the effects of induced traffic volume due to the implied flow improvement.

The reduction in emissions and resultant CO concentrations attributed to the combined strategies (Strategy 3) is greater than the reduction of the individually applied strategies shown in the table. The additional reduction is a result of the reduction in VMT which would occur if vehicle restraints are applied to maintain the level of traffic flow improvement suggested by Strategy 2.

Table N.Y.3 summarizes the annual emission totals for the entire grid network for each transportation control dition. These values can be used for "rollback" calculations for the New York area.

3.3.2.2 Hydrocarbons

Table N.Y.2 summarizes the maximum HC concentrations and emissions predicted for the grid area. Figure N.Y.2 shows the location of these maxima for each transportation control condition. The total emissions shown in the table reflect the importance of stationary hydrocarbon sources in the New York area. The impact of these sources increases as the mobile source emissions are decreased. For the purpose of analyzing the impact of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than the resultant concentrations.

Mobile source hydrocarbons are predicted to decrease by approximately 44 percent by 1977 due to the emission control devices required by the Federal new source standards. This reduction could be maintained and an additional 12 percent reduction in 1977 mobile emissions achieved by an inspection and maintenance program (Strategy 1).

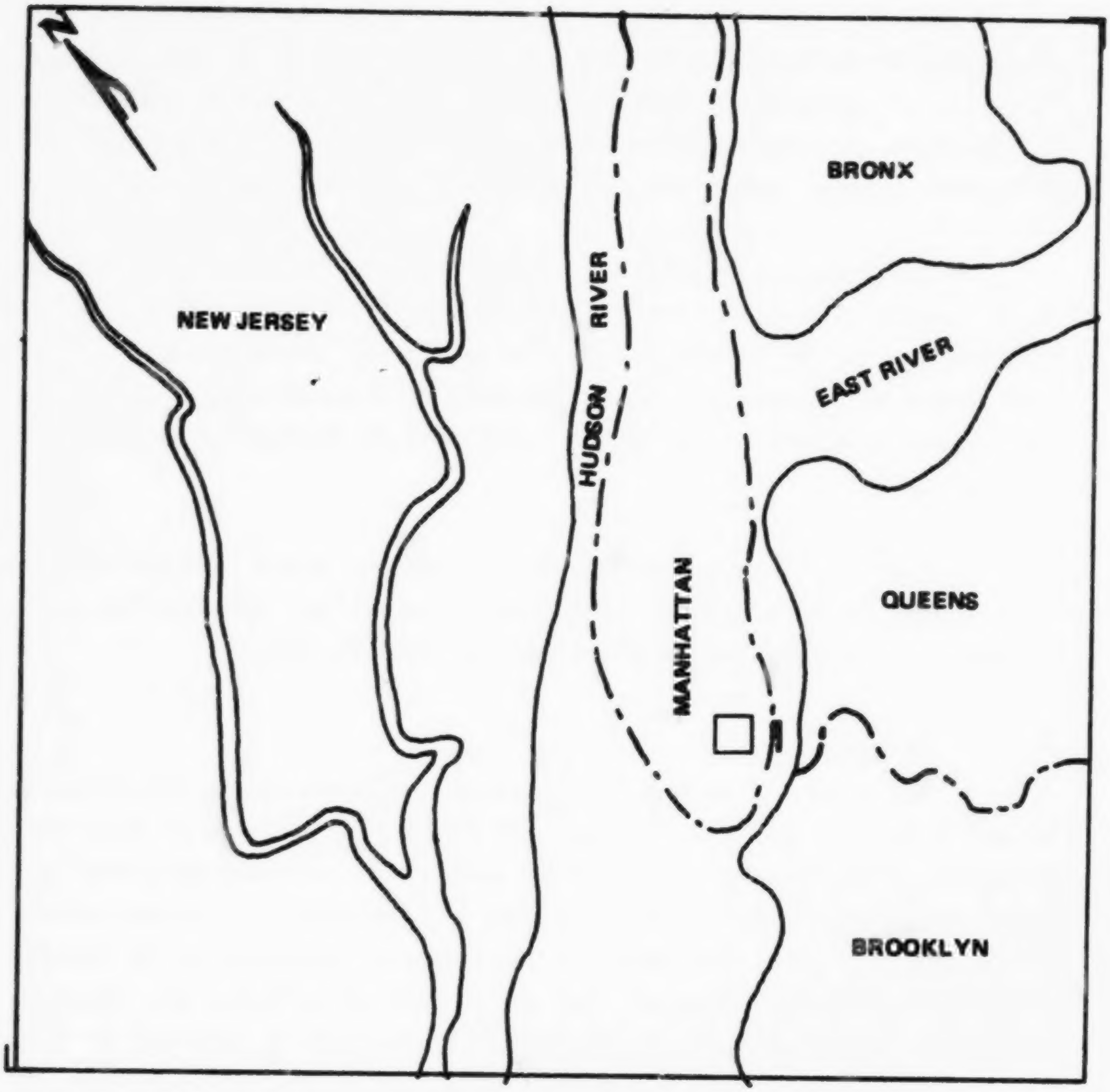

N
NEW JERSEY
HUDSON RIVER
MANHATTAN
BRONX
EAST RIVER
QUEENS
BROOKLYN

Figure N.Y.2. Maximum Concentration Location for All Pollutants for All Conditions Listed in Tables N.Y.1 and N.Y.2.

HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1970	4451 (134)[1]	3610 (134)	4200 (134)	6300 (134	4400 (134)	7600 (134)
1977	2609 (134)	2031 (134)	2400 (134)	3500 (134)	2500 (134)	4200 (134)
Strategy 1	2364 (134)	1768 (134)	2100 (134)	3100 (134)	2200 (134)	3700 (134)
Strategy 2	2588 (134)	2010 (134)	2300 (134)	3400 (134)	2400 (134)	4100 (134)
Strategy 3	2169 (134)	1591 (134)	1900 (134)	2800 (134)	2000 (134)	3400 (134)

[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure N.Y.2 for location of these maxima for CO, HC, and NO_x, respectively.

[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table N.Y.2. Predicted Maximum Emissions and Concentrations

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1970	1262410	1164965	306877	208599	333684	94285
1977 (uncontrolled)	553098	482900	159741	67735	209057	66844
Strategy 1	504370	434172	151661	59655	NA	NA
Strategy 2	547056	476858	159022	67016	NA	NA
Strategy 3	456064	385866	145125	53119	202373	60160

Table N.Y. 3. Annual Emissions (tons/year) for the Area Shown in Figure N.Y. 1.

The extremely low average vehicle speeds in major portions of the metropolitan area during peak traffic hours result in very high emission rates. Strategy 2 (Traffic Flow Control) is slightly effective in reducing hydrocarbon emissions by increasing the average speeds in these congested areas. An approximately 11 percent reduction in mobile source emissions is achieved by application of this strategy to the projected 1977 data base.

Strategy 3 (Combined Strategies) provides the vehicle restraints necessary to maintain the level of traffic flow control achieved by Strategy 2. VMT reduction may be achieved by the implementation of vehicle restraints and this would provide an additional 10 percent (approximately) reduction in mobile source hydrocarbon emissions.

Table N.Y.3 lists the predicted annual hydrocarbon emissions for the entire grid network. The emissions in this table can be used for "rollback" calculations.

3.3.2.3 Oxides of Nitrogen

NO_x emissions and maximum concentrations in the grid area are shown in Table N.Y.1. Figure N.Y.2 shows the location of the maximum concentration for each of the transportation control conditions considered. It can be seen from the table that the maximum concentrations are grossly affected by stationary sources for which no control is expected by 1977. For the purpose of analyzing the impact of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than resultant concentrations.

The 1977 uncontrolled mobile emissions show a reduction of approximately 28 percent over base year mobile source emissions. This reduction is the result of automotive controls expected to be installed. Whether this reduction in mobile sources will be sufficient to produce any major reduction in ambient concentrations will depend on the impact of stationary source emissions on the concentrations which cannot be adequately described with this model.

Table N.Y.3 lists the predicted annual emissions for NO_x for the entire grid network for each transportation control condition. Both total and mobile source emissions are given. The annual emissions from this table can be used for "rollback" calculations if desired.

3.4 METROPOLITAN AREA ANALYSIS - DENVER

3.4.1 Data Base and Methodology

3.4.1.1 Transportation Data

- Basic Data

Basic data were provided by the Colorado State Department of Highways and consisted of vehicle miles traveled and speed data for the 156 districts comprising the Denver Metropolitan area. The data covered annual average weekday travel in 1969 and 1990. It was part of the 1970 Denver Urban Impact Study and represented travel within a line defined as the "urban-in-fact" boundary for January 1, 1970, and included the developed fringe of the Denver urbanized area.

Also provided was information on travel on city streets. The Colorado Highway Department estimated approximately 850,000 VMT in 1969 on local streets and indicated it probably should be about equally distributed among each of the 156 districts. The local street VMT estimate for 1990 was 1.34 million miles of vehicle travel. The speed for both 1969 and 1990 for local street VMT was assumed to be 17 mph.

Speed data were based on the Speed Report for the 1970 traffic assignment model showing speed data by functional class and area. (Basic raw material provided from DRCOG(3) 1970 Travel Time Study)

- Interpolation Factors

The interpolation procedure used in obtaining 1977 VMT for each district may be summarized as follows:

$$1977\ \text{VMT} = A\,[1969\ \text{VMT} + B(1990\ \text{VMT} - 1969\ \text{VMT})]$$

Explanation for "B"

"B" is an interpolation factor based on DRCOG "Population Estimates and Projections: 1970 Census Tracts - Denver SMSA, 1968-1975-1990-2010." For each district,

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(3) Denver Regional Council of Governments.

$$B = \frac{\text{Percent increase in population from 1969 to 1977}}{\text{Percent increase in population from 1969 to 1990}}$$

Explanation for "A"

The DRCOG "Population Estimates and Projections" utilized were interpolated in the above manner to estimate 1970 population by district. Actual population figures provided by the 1970 Census were found to differ, in some cases substantially. It was felt that the VMT projections supplied would be based on similar information as that utilized in the DRCOG population projections and, hence, would exhibit similar deviations from actual experience. In particular, it would appear that variances in population estimates resulted primarily from unanticipated changes in migration patterns and that migrants probably tend to be over-represented as a proportion of population since a high proportion are employed. Consequently, it was felt that an adjustment to 1977 VMT should be made reflecting new data supplied by the 1970 Census. Accordingly, as a rough adjustment, the 1977 VMT for each district is multiplied by "A", which is the ratio of 1970 actual population to 1970 estimated population.

- Estimates of Eight- and Peak-Hour VMT and Speed

The estimates of daily traffic variation was based on the following information:

a. A distribution of appropriate counting stations which showed the 24-hour daily variation based on Interstate daily count locations and provided the means of deriving daily one-hour peak and eight-hour peak shares of traffic.

b. Twenty-four hour downtown street traffic variation based on manual counts expanded into 10-hour machine controlled counts (10-minute counts per hour basis for sampling).

Based on these data and using weighted averages, it was estimated that eight-hour VMT is 53.4 percent of the 24-hour VMT; and the one-hour maximum VMT revised is 9.3 percent of 24-hour VMT.

Using the DRCOG "1970 Travel Time Study" (which provided peak-hour, a.m. and p.m., and off peak-hour, directional, average speeds), comparisons were made for three major arteries (Broadway, Colorado, and Federal) between mean-peak hour and mean off peak-hour speeds. On the average, (though with a wide variation) peak-hour speeds were 77 percent of off peak-hour speeds.

3.4.1.2 Meteorological Data

Seasonal average wind speeds and directions were obtained from national climatological data charts. It should be noted that these averages represent typical cases for the area and are applied only to given representative samples of the possible dispersion patterns for the area. The Denver basin is an area as described in Section 2.3 where physical and meteorological conditions can create high pollution potentials which are not defined by the model. Therefore, the "worst case" maximum concentrations predicted may not agree closely with recorded ambient maximums.

3.4.1.3 Stationary Sources

The 1969 and 1977 county total stationary source contributions for each pollutant were estimated from the Colorado Implementation Plan. The totals were distributed to the grids within the counties using VMT as an apportioning factor.

3.4.2 Summary of Results

The following discussion presents the impact of the transportation controls on each of the three pollutants considered. Figure Den.1 shows the analysis area.

3.4.2.1 Carbon Monoxide

Table Den.1 summarizes the maximum emissions and concentrations predicted for carbon monoxide for each of the applied transportation conditions. (See Figure Den.2.) This maximum area is surrounded by several high concentration areas closely associated with major highway intersections near the city limits.

Stationary sources are treated as background emissions as described in Section 3.4.1.3. This procedure has a very minor effect on CO emissions because these sources represent only about 1 percent of the total CO emissions in Denver.

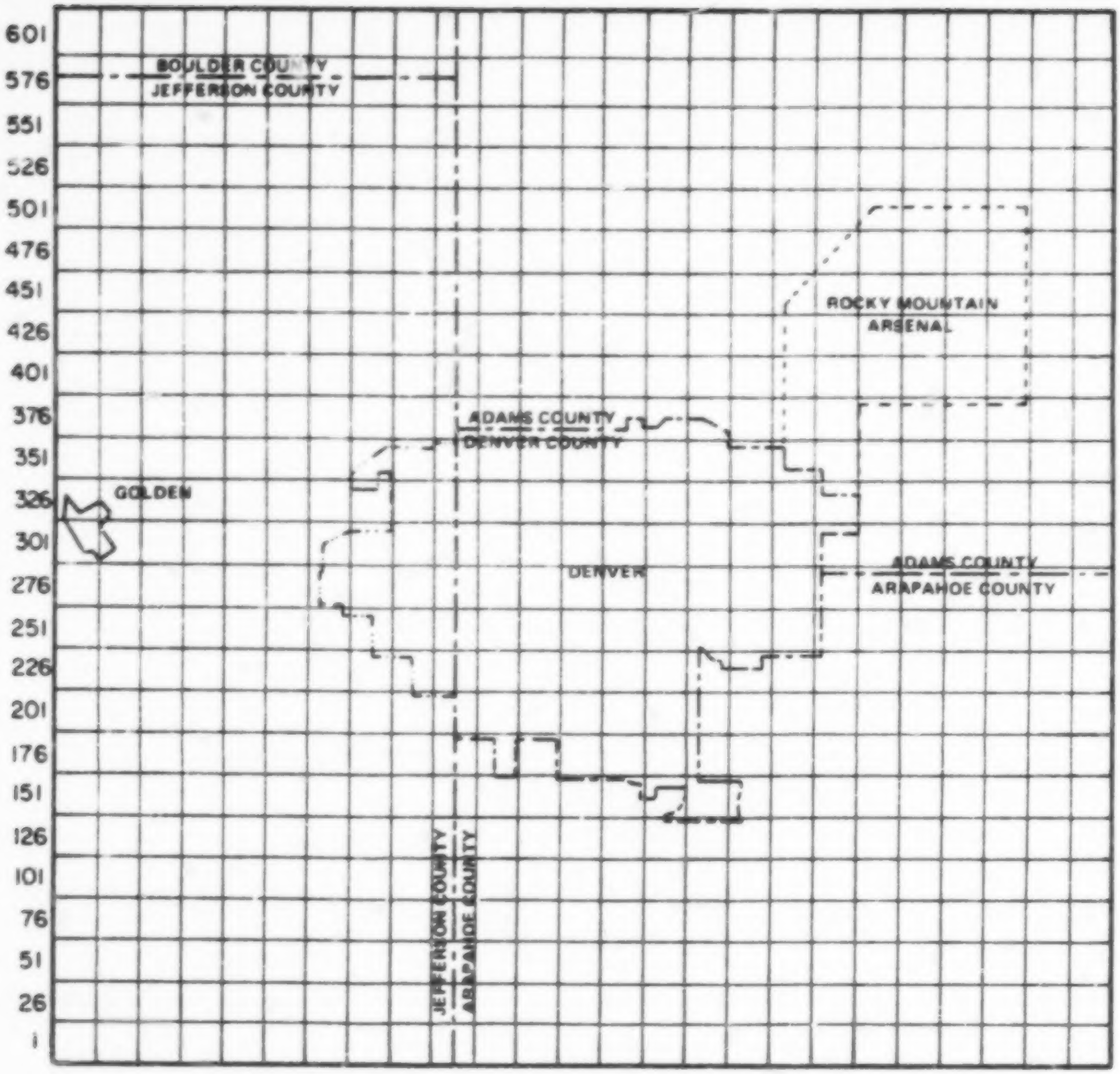
The 1969 or base year estimates shown in Table Den.1 predict current "worst case" conditions exceed the eight-hour maximum federal standard. By 1977, the model predicts that a 52 percent reduction in mobile source emissions due to internal automotive controls will bring the eight-hour maximum levels well within the federal standards.

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1969	13394 (288)*	12980 (288)	12.7537 (288)	20.1236 (288)
1977	6724 (288)	6279 (288)	7.4960 (289)	11.0922 (289)
Strategy 1	6096 (288)	5651 (288)	6.0453 (289)	9.9917 (289)
Strategy 2	6674 (288)	6229 (288)	7.5343 (289)	10.9526 (289)
Strategy 3	5770 (288)	5325 (288)	6.5 (289)	9.4 (288)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1969	2947 (288)	260 (288)	1700 (288)	1800 (288)
1977	3104 (288)	212 (288)	1800 (288)	1800 (288)
Strategy 3	3094 (288)	201 (288)	1800 (288)	1800 (288)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure Den.2 for location of these maxima for CO, HC, and NO_x, respectively.

Table Den. 1. Predicted Maximum Emissions and Concentrations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301
276
251
226
201
176
151
126
101
76
51
26
1
BOULDER COUNTY
JEFFERSON COUNTY
ROCKY MOUNTAIN ARSENAL
ADAMS COUNTY
DENVER COUNTY
GOLDEN
DENVER
ADAMS COUNTY
ARAPAHOE COUNTY
JEFFERSON COUNTY
ARAPAHOE COUNTY

Figure Den.1. Grid Network

Total Area = 625 mi^2

Grid Area = 1 mi^2

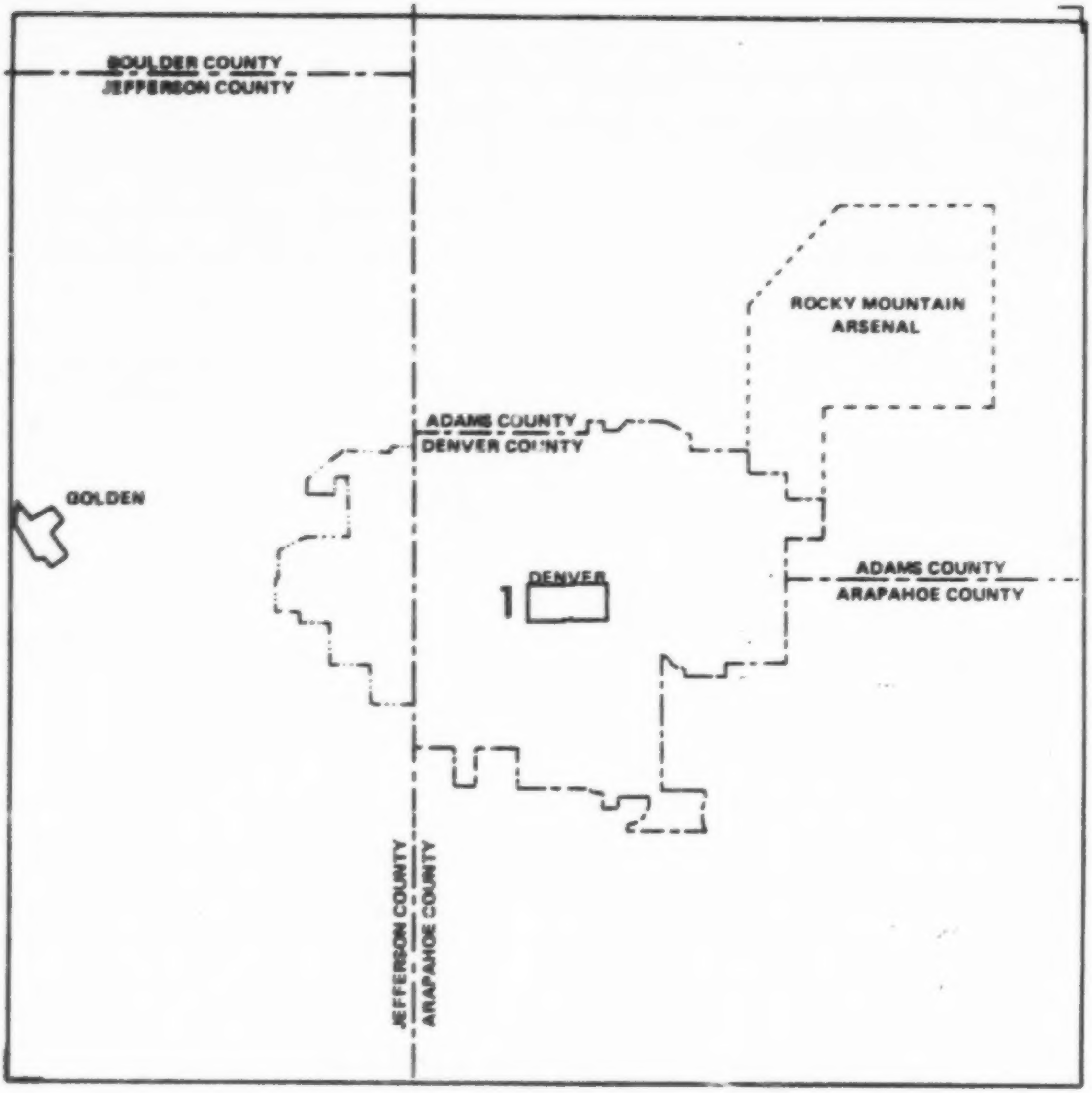

BOULDER COUNTY
JEFFERSON COUNTY
ROCKY MOUNTAIN
ARSENAL
ADAMS COUNTY
DENVER COUNTY
GOLDEN
DENVER
1
ADAMS COUNTY
ARAPAHOE COUNTY
JEFFERSON COUNTY
ARAPAHOE COUNTY

Figure Den.2. Maximum Concentration Location for All Pollutants for All Transportation Conditions Listed in Table Den.1 and Den.2.

An inspection and maintenance program (Strategy 1) would reduce the predicted 1977 mobile emissions by approximately 10 percent. This would not have a marked influence on predicted concentrations; however, it would insure that the automotive emissions did not increase above the level attributed to emission control devices.

Strategy 2 (Traffic Flow Controls) assumes an average increase in vehicle speeds. The impact of this strategy would be almost negligible because of the relatively high average speeds projected for 1977.

The approximately 15 percent reduction in emissions produced by the combined strategies (Strategy 3) is greater than the sum of emission reductions from Strategies 1 and 2 because of the vehicle restraints applied to maintain the desired level of traffic flow control. These vehicle restraints will produce an additional small percentage reduction in total VMT which increases the total effectiveness of this strategy.

Table Den.3 summarizes the annual emissions total for each pollutant for the entire grid network for each transportation control condition. These values can be used in "rollback" calculation formulas if desired.

3.4.2.2 Hydrocarbons

Maximum hydrocarbon emissions and resultant concentrations predicted for each transportation condition are given in Table Den.2. Figure Den.2 shows the location of the maximum concentrations listed in the table. The location of these maxima does not vary from pollutant to pollutant. This is primarily a result of the treatment of stationary sources as background emissions. Since these sources vary directly with the mobile source strength, the resultant distribution patterns are representative of the mobile source data although the absolute concentration values are greatly affected by the stationary source contribution.

HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1969	4496 (288)[1]	1633 (288)	3100 (288)	4000 (288)	3000 (288)	3100 (288)
1977	3733 (288)	648 (288)	2300 (288)	2600 (288)	2300 (288)	2400 (288)
Strategy 1	3655 (288)	570 (288)	2200 (288)	2500 (288)	2200 (288)	1900 (288)
Strategy 2	3728 (288)	644 (288)	2300 (288)	2600 (288)	2300 (288)	2000 (288)
Strategy 3	3622 (288)	538 (288)	2200 (288)	2500 (288)	2200 (288)	1900 (288)

[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure Den.2 for location of these maxima for CO, HC, and NO_x, respectively.

[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table Den.2. Predicted Maximum Emissions and Concentrations

The 1977 uncontrolled mobile source hydrocarbon emissions are reduced by approximately 60 percent over base year (1969) emissions by required Federal automotive controls. An inspection and maintenance program suggested by Strategy 1 would insure the efficiency of automotive control devices and yield an additional 12 percent reduction in 1977 mobile hydrocarbon emissions.

Strategy 2 (Traffic Flow Controls) would reduce 1977 mobile source emissions by less than one percent. This strategy would probably have a negligible effect on concentration values unless combined with extensive vehicle restraints.

The combined traffic flow control and vehicle restraints suggested in Strategy 3 would reduce 1977 mobile source (uncontrolled) emissions by approximately 17 percent. Part of this reduction is attributable to a small percentage VMT reduction resulting from vehicle restraints.

Table Den.3 summarizes the predicted total annual emissions for the entire grid network. The hydrocarbon emissions given in this table can be used for "rollback" calculations if desired.

3.4.2.3 Oxides Of Nitrogen

Table Den.1 summarizes the maximum concentrations and maximum emissions for NO_x in the grid area. Figure Den.2 shows the location of the maximum concentrations. It can be seen from the table that predicted concentrations values are grossly affected by stationary source contributions. For the purpose of analyzing the impact of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than the resultant concentrations.

The 1977 uncontrolled mobile source emissions show approximately a 18 percent reduction over 1969 emissions.

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1970	405682	394666	83400	50562	53469	6998
1977	335516	323109	70597	33584	61947	11852
Strategy 1	303189	290783	66554	29539	NA	NA
Strategy 2	332296	319890	70291	33277	NA	NA
Strategy 3	285898	273491	64820	27806	61355	11260

Table Den. 3. Annual Emissions (tons/year) for the Area Shown in Figure Den. 1.

Strategy 3 (Combined Strategies) is the only transportation control strategy with a direct impact on NO_x emissions. The approximate 5 percent reduction in mobile source emissions over 1977 uncontrolled emissions is a result of a small percentage VMT reduction due to vehicle restraints.

3.5 METROPOLITAN AREA ANALYSIS - SAN FRANCISCO

3.5.1 Data Base And Methodology

3.5.1.1 Transportation Data

- Basic Data

The Metropolitan Transportation Commission of the San Francisco Bay Area provided basic VMT and speed information used for the analysis. The following data were provided in the form of computer printouts for the 1965 "G" Network (existing system) and the 1980 "X" Network (committed highways and transit):

a. Node location list and maps.
b. Loaded link volumes, distance, and speed.
c. Trip end table by zone.
d. Vehicle mile summary (by county)

From these data, estimates of zonal VMT and speed were developed. Because the VMT and speed data were only given by link (approximately 2000 links), zonal estimates had to be developed.

In addition to the above data, additional items of information were provided as regards employment (and projections to 1990), modal splits, traffic forecasts and screenline counts. The latter data were used for calculation of the one- and eight-hour peak VMT periods.

- Estimating VMT by Zones

The estimates for each of the 291 zones in the San Francisco area for 1965 and 1980 were obtained as follows:

1. Trip end summaries for 1965 and 1980 provided Origination/Productions, Destination/Attractions and Intrazonal trips for each zone. All these trip ends were summed and the total trips for each zone were divided by the grand total of all trips for all zones to obtain for each zone the percent of total. The percent trips for zones were then summed into counties to give the percent trips for each county.

2. Using total vehicle miles (VMT) available by county for 1965 and 1980, the VMT for each zone was estimated as:

$$\text{ZONE VMT} = \frac{\text{COUNTY VMT} \times \text{\% TRIPS BY ZONE}}{\text{\% TRIPS BY COUNTY}}$$

3. Because no relevant information was available for intermediate years, a linear interpolation for each zone was used to obtain estimates of 1970 and 1977 VMT from 1965 VMT.

In connection with this approach, it should be noted that this method does not permit accurate distribution of the VMT (trips) between zones especially between two widely separate zones. However, lack of available alternate data for link totals (within the time constraints and costs of the project) did not permit totalling links for each zone. Conversations with representatives of the California Highway Department indicated that the method used above would not introduce serious error, especially in view of the fact that VMT was to be used as a zone average, in any case, rather than a zone-to-zone measure.

- Estimating Eight- and One-Hour Maximum VMT

Hourly traffic data for 24 hours were unavailable for most of the San Francisco region (within the time limits set by the project). However, traffic counts were available for two major gateways (the Caldecott Tunnel and the Bay Bridge Toll Plaza) for the spring of 1970 and 1971. Based on these data, hourly distribution percentages were calculated. These distributions were then related to 12-hour cordon counts, and estimates were devised for the one- and eight-hour VMT. The results were as follows:

One-Hour peak VMT as a percent of the 24-hour total - 10 percent.

Eight-Hour peak VMT as a percent of the 24-hour total - 50 percent.

- Estimating Zone Speeds

The computer printouts provided by the Highway Department of California provided no zonal speed data -- only link speeds. In order to estimate zone speeds to be used in the calculation of zonal or grid emissions, it was necessary to develop an estimating procedure for arriving at an average speed for each zone. From the printouts, speeds and volumes were available for 1965 links in the San Francisco area. Approximately 2000 links were designated for the Bay Area Transportation Study (BATS). If all links were to be used to arrive at a weighted average speed, a 2000 x 2000 link matrix would have had to be used to develop the average speed and then assigned to almost 300 zones.

Within the time and budget constraints of the project, such an effort was clearly not possible. Furthermore, time and budget limitations precluded the possibility of developing a special program to process the information available on the computer tapes. It was, therefore, necessary to develop a sampling procedure that would provide representative speed values.

To do this, the most important links (in terms of volume of traffic) were identified for all the links included in the printouts. Staff was assigned to review the volumes on the computer printouts for 1965 data, and key link information was segregated by county along with speed shown for each of these key links. After an initial list of key links was developed, it became apparent that additional undivided arterial and city street data would have to be added and these additional link speeds and volumes were developed for each of the counties in the BATS area. Using the estimated link speeds and volumes identified for each county, a weighted average speed was calculated for each county and this calculated speed value was then assigned to the traffic zones within the county.

A similar procedure was used for both 1965 and 1980 using the assigned link speeds in both periods weighted by their associated volumes. The following summarizes the key steps:

1. Identify the key (large traffic volume) links in each county and plot them on the link maps.
2. Fill out the link data so plotted with additional links (speed and volumes) for city streets and undivided arterials (since we found the high traffic volume links initially plotted to be mostly freeway).
3. The adjusted link maps were then overlaid with the zone maps and the speed and volume data plotted on these zonal maps to assure coverage in each major county area.
4. The data developed from the above steps were then put into tabular form and a weighted average speed was calculated using volumes as weights.
5. These average speeds were then assigned to appropriate zones in each county in the BATS study area.

The table below summarizes the estimated speed values calculated for major counties by zone for peak-hour, eight-hour, and 24-hour periods for 1965 and 1980. Description of the steps used for calculating speed variations in time are included in the following table.

3.5.1.2 Meteorological Data

Seasonal average wind speeds and directions were obtained from national climatological data charts. It should be noted that these averages represent typical cases for the area and are applied only to give representative samples of the possible dispersion patterns for the area.

3.5.1.3 Stationary Sources

1970 and 1977 total stationary source emissions were estimated from the Implementation Plan for California. These emissions were distributed throughout the analysis area using VMT as an apportioning factor. Table S.F.3 shows the impact of these sources on total emissions for 1970 and 1977 for each pollutant.

County	Zones (inclusive)	Speed Values (mph)					
		24 hours		8-hour max. VMT		1-hour max. VMT	
		1965	1980 (Calc.1)	1965 (Calc.3)	1980 (Calc.3)	1965 (Calc.2)	1980
San Francisco							
CBD	1-8,39-40	22	21	21.5	20.5	21	20
All Other	9-38	49	46	46	43	43	40
Marin	41-57	40	48	34.5	41.5	29	35
San Mateo	58-91	44	48	38	41.5	32	35
Sonoma	92-101	38	42	32	35.5	26	29
Napa	102-110	35	42	31.5	38	28	34
Solano	111-125	39	42	32.5	35	26	28
Contra Costa	126-160	48	51	41.5	44	35	37
Santa Clara	161-222	38	43	33.5	38	29	33
Alameda	223-291	48	49	42	43	36	37

Steps for calculating hourly variations by county and zone were as follows:

Calculation 1: 1980 24-hour Speed

a. 1980 24-hour Speed calculated by using Speed and 1980 volumes

b. Using calculations developed for 1965, 1980 Speed values were substituted for 1965 Speed values whenever they were different than the 1965 Speed values.

c. The "adjusted speed" (as in b. above) was weighted by 1980 volumes and a weighted average derived.

Calculation 2: 1965 1-hour Speed

a. Develop factor for 1965 peak hour speed by taking the percentage ratio: $\frac{\text{1980 peak hour speed}}{\text{1980 24-hour speed}} \times 100$

b. Apply this ratio to 1965 24-hour speed values.

Calculation 3: 1965 and 1980 8-hour Speed

a. 1965 and 1980 eight-hour maximum estimated as the mid-point of the one-hour and 24-hour speed values.

3.5.2 Summary of Results

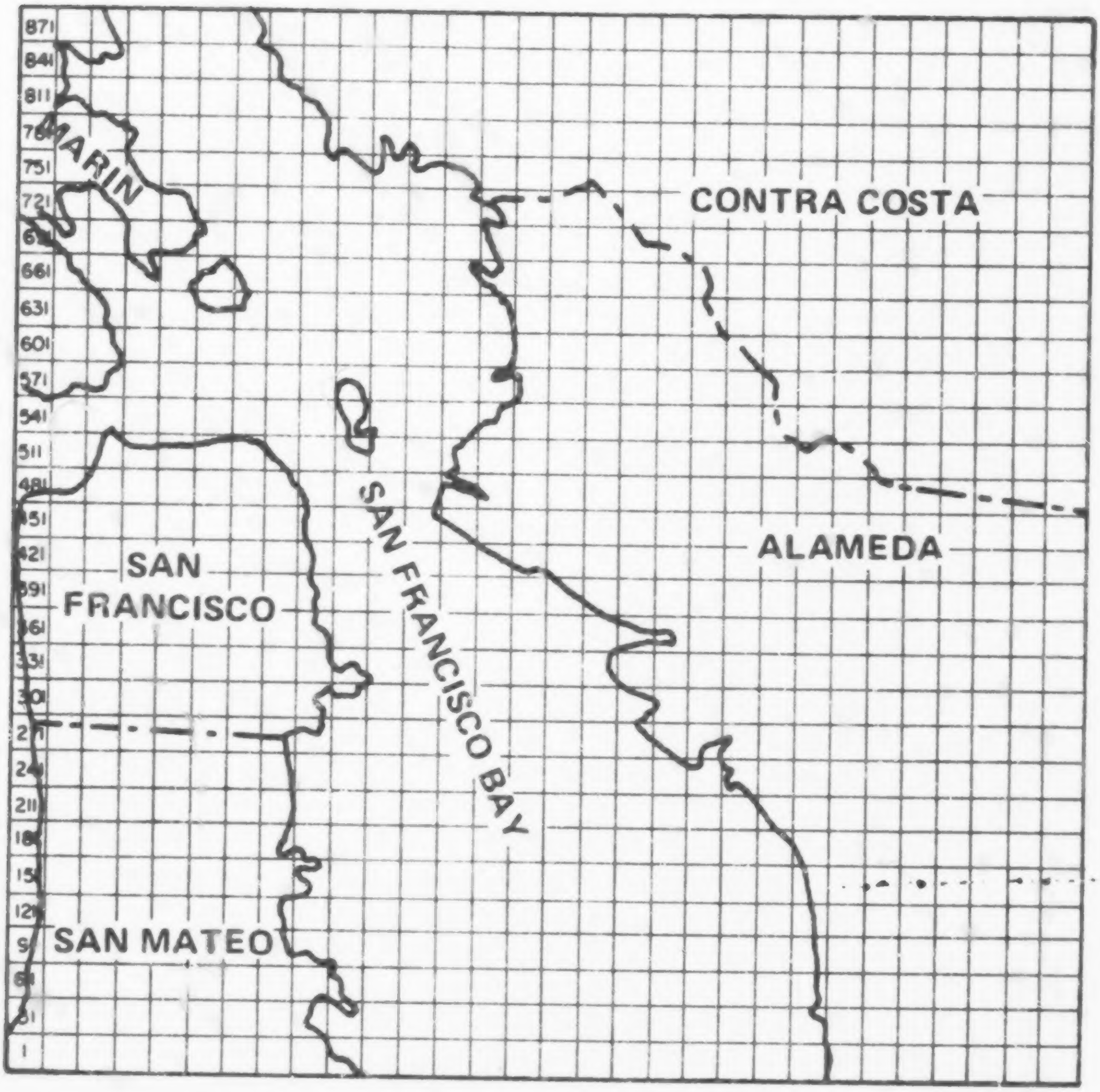
The following discussion presents the impact of these transportation controls on each of the three pollutants considered. Figure S.F.1 represents the analysis area.

3.5.2.1 Carbon Monoxide

Table S.F.1 summarizes the maximum emissions and maximum concentrations predicted for carbon monoxide for each of the applied control strategies and the uncontrolled cases. The areas of maximum concentration are centered in the city business areas and bridge approaches. (See Figure S.F.2.) Other high concentration areas include the towns of Oakland and Richmond.

Stationary sources are treated as background emissions as described in Section 3.5.1.3. This procedure does not have a critical effect on CO emissions or concentration patterns in San Francisco because stationary sources represent a very small percentage of total CO emissions in this area (approximately 6 percent).

The 1977 predictions given in Table S.F.1 show the effect of emission control devices on the maximum eight-hour and peak-hour concentrations. The 1968 maximum emissions are reduced by 35 percent. This reduction does not appear to be as great for San Francisco as it is in most of the other major metropolitan areas considered. The impact of the younger automotive age distribution is reflected in the predicted 1970 maximum concentrations. The peak-hour maximum is well below the 40 mg/m^3 standard and the predicted eight-hour maximum barely exceeds the 10 mg/m^3 standard. The 35 percent reduction in emissions by 1977 may be sufficient to bring the eight-hour maximum concentration within Federal guidelines without further controls; however, under severe stagnation conditions ($<$2.5 meters/second wind speeds) the eight-hour standard may be exceeded.


871
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211
1
MARIN
CONTRA COSTA
ALAMEDA
SAN FRANCISCO
SAN FRANCISCO BAY
SAN MATEO

Figure S.F.1. San Francisco Grid Network

Total Area = 900 mi^2

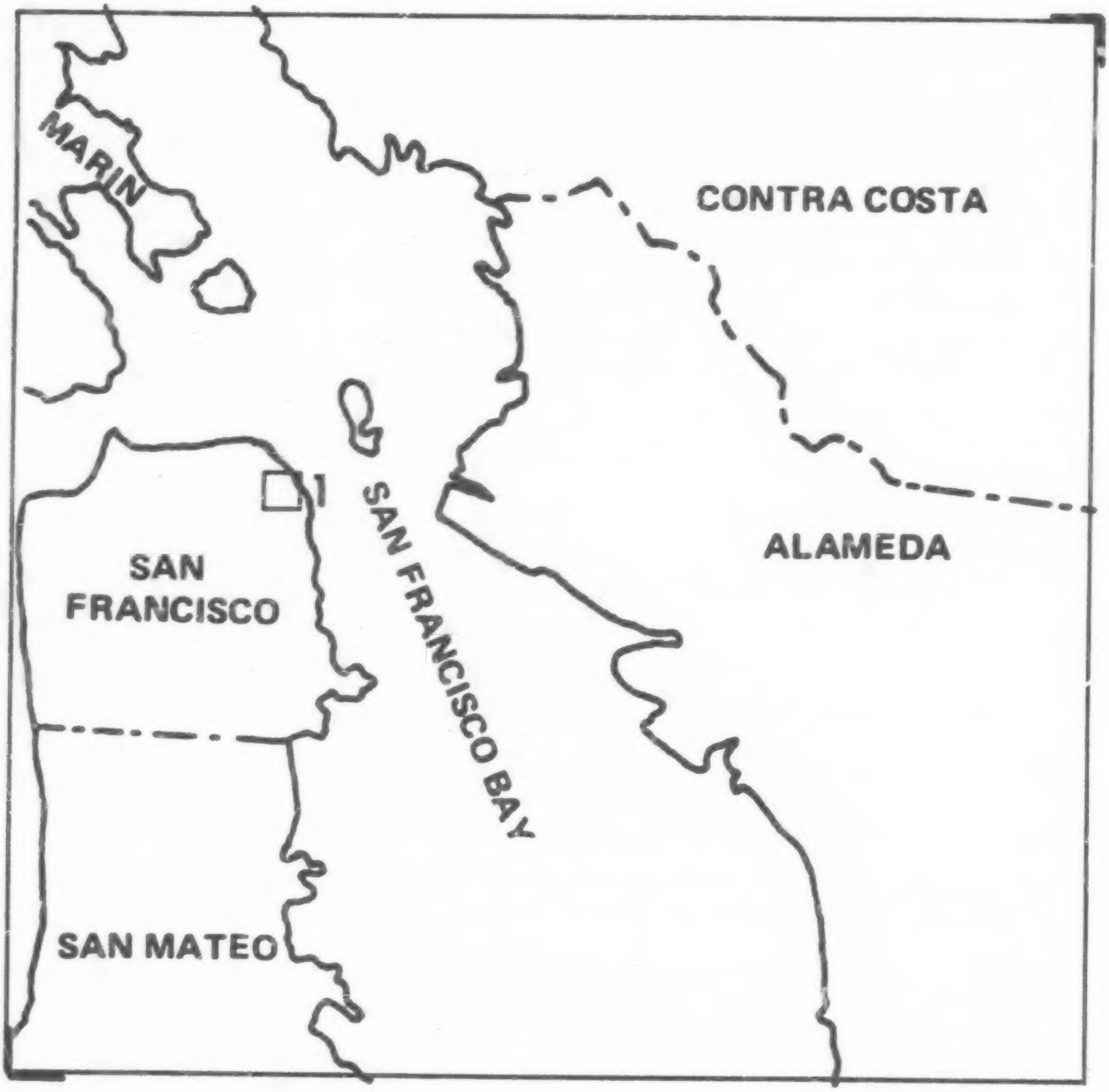
Grid Area = 1 mi^2

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1970	12508 (488)*	11767 (488)	12.2 (488)	20.5 (488)
1977	9039 (488)	8443 (488)	8.5 (488)	14.4 (488)
Strategy 1	8196 (488)	7600 (488)	7.7 (488)	13.0 (488)
Strategy 2	8512 (488)	7916 (488)	8.1 (488)	12.9 (488)
Strategy 3	7009 (488)	6413 (488)	6.6 (488)	10.5 (488)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1970	1894 (488)	1245 (488)	1500 (488)	2200 (488)
1977	1564 (488)	1042 (488)	1200 (488)	1800 (488)
Strategy 3	1451 (488)	929 (488)	1100 (488)	1600 (488)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure S.F.2 for location of these maxima for CO, HC, and NO_x, respectively.

Table S.F.1. Predicted Maximum Emissions and Concentrations


MARIN
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ALAMEDA
SAN FRANCISCO BAY
SAN MATEO

Figure S.F.2. Maximum Concentration Location for All Pollutants for All Transportation Conditions Given in Table S.F.1 and S.F.2.

An inspection and maintenance program (Strategy 1) would reduce the predicted 1977 emissions by approximately 10 percent. This would not have a marked influence on predicted concentrations; however, it would insure that the automotive emissions do not increase above the level assumed in the uncontrolled cases, i.e., that the control device efficiency does not significantly deteriorate.

Strategy 2 (Traffic Flow Controls) assumes an average increase in vehicle speeds. The impact of this strategy may not be adequately represented because the speed data base is insufficiently detailed. (See Section 3.5.1.1). However, it appears that this strategy would have a negligible effect on concentration values in the Bay Area.

The reduction in emissions produced by the combined strategies (Strategy 3) is greater than the sum of reductions from the individual strategies because of the added emission reduction achieved by a small percentage VMT reduction. This VMT reduction is a result of vehicle restraints which must be applied to maintain the average vehicle speed increase provided by the traffic flow controls. The combined emission reduction would be approximately 20 percent of the 1977 uncontrolled vehicle emissions and may be sufficient to maintain maximum concentration values at below standard levels.

Table S.F.3 summarizes the annual emission totals for all pollutants for the entire grid network for each transportation control condition. These values can be used for "rollback" calculations if desired.

3.5.2.2 Hydrocarbons

Table S.F.2 includes the maximum emissions and concentrations predicted for each transportation condition for hydrocarbons. Figure S.F.2 shows the location of the maximum concentrations predicted. The location of this maximum does not vary from pollutant to pollutant because of lack of detail in the data base. (See Section 3.5.1.) It should be recalled that stationary sources are treated as a percentage of the total emissions and, therefore, vary directly with mobile source emissions. Therefore, although the absolute

HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1970	3379 (488)[1]	1963 (488)	2800 (488)	4100 (488)	5100 (488)	6500 (488)
1977	2273 (488)	1153 (488)	1800 (488)	2500 (488)	3300 (488)	4000 (488)
Strategy 1	2135 (488)	1015 (488)	800 (488)	1100 (488)	1400 (488)	1700 (488)
Strategy 2	2220 (488)	1082 (488)	900 (488)	1200 (488)	1600 (488)	1900 (488)
Strategy 3	1975 (488)	837 (488)	600 (488)	900 (488)	1100 (488)	1400 (488)

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[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figure S.F.2 for location of these maxima for CO, HC, and NO_x, respectively.

[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table S.F.2. Predicted Maximum Emissions and Concentrations

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1970	422100	397081	108384	62983	49891	32801
1977	258594	241123	60468	31461	44317	25286
Strategy 1	234294	216823	54176	25169	NA	NA
Strategy 2	245519	228048	59085	30078	NA	NA
Strategy 3	202029	184558	50141	21134	41582	22551

Table S.F. 3. Annual Emissions (tons/year) for the Area Shown in Figure S.F. 1.

value of the predicted concentrations is greatly influenced by the stationary sources which contribute approximately 42 percent of the hydrocarbon emissions in the Bay Area, the distribution patterns are representative only of the mobile sources. It should also be noted that the impact of the stationary source emissions on predicted concentration values increases markedly as automotive emission control is increased.

The 1977 uncontrolled hydrocarbon mobile source emissions are reduced by approximately 42 percent over base year (1970) emissions by internal automotive controls. Whether this reduction would be sufficient to bring ambient concentration values within Federal guidelines is not apparent from the model concentration predictions.

An Inspection and Maintenance program suggested in Strategy 1 would reduce the deterioration of automotive control devices and decrease the 1977 predicted mobile emissions by an additional 12 percent.

Strategy 2 (Traffic Flow Controls) would reduce 1977 mobile source emissions by less than 5 percent. This strategy would probably have little effect on concentration values unless combined with extensive vehicle restraints.

Combined traffic flow control and vehicle restraints suggested for Strategy 3 would reduce 1977 mobile source emissions by approximately 15 percent. Part of this reduction is attributable to a small VMT reduction associated with major vehicle restraints.

Table S.F.3 summarizes the predicted total annual emissions for the entire 900 mi^2 grid network. The hydrocarbon emissions in this table can be used for "rollback" calculations if desired.

3.5.2.3 Oxides of Nitrogen

Table S.F.1 summarizes the maximum concentrations and maximum emissions for NO_x in the grid area. Figure S.F.2 shows the location of these maxima. It can be seen from the table that the predicted concentrations are grossly affected by stationary sources. For the purpose of analyzing the impact of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than resultant concentrations.

The 1977 uncontrolled mobile source emissions show approximately a 16 percent reduction in NO_x emissions from 1977 uncontrolled emissions. This reduction is a result of required internal automotive controls.

Strategy 3 (Combined Strategies) is the only transportation control strategy with an impact on NO_x emissions. The approximately 10 percent reduction in mobile source 1977 emissions is due to the VMT reduction implied by vehicle restraints.

Table S.F.2 lists the predicted annual emissions for NO_x for the entire grid network for each transportation control condition. Both total emissions and mobile source emissions are given. The emissions from this table can be used for "rollback" calculations if desired.

3.6 METROPOLITAN AREA ANALYSIS - LOS ANGELES

3.6.1 Data Base And Methodology

3.6.1.1 Transportation Data

- Basic Data

The California Division of Highways, District 7 Office, provided the basic information required to undertake the VMT and emission analysis for the Los Angeles area. Specifically, the following data were provided for 1967 and 1980:

1. Vehicle miles for zonal and intrazonal VMT grouped according to Regional Analysis Zones (RAZ).
2. Intrazone trips and path values (in minutes for 1967 Study Zones).
3. Intrazone frequency distribution.
4. Set of 1967 zone maps showing RAZ boundaries.
5. Los Angeles Regional Transportation Study area road map showing the location of 24-hour traffic counts.
6. Set of 24-hour traffic counts by hour. The location of these counts are shown on the LARTS area road map.
7. Plots of 1967 and 1980 networks and network maps.
8. Cordon counts for downtown Los Angeles.
9. Population, housing, and employment data showing Southern Calif. Assoc. of Govt. decennial figures for 1970 through 2020.
10. Economic summary data for the LARTS area showing vehicle trips, miles and minutes for 1967 and 1980.
11. Automobile ownership data for the Los Angeles Metropolitan area.
12. Regional maps.

Vehicle miles were calculated for all regional analysis zones (approximately 120), and the 20 regional analysis zones that had been under consideration for exclusion were finally included as part of the basic VMT measures provided by the California Highway Department. Because the gravity model used to generate VMT did not include any capacity constraints, some links were probably overloaded. Unfortunately, no downward adjustment could be made for these overloaded links.

The 1980 networks that were used were those designated as "Alternative E-F." This alternative is considered by the Division of Highways as the one most likely to be constructed. "Alternative E-F" includes all of Interstate 105 and 210; Route 118 completed in Ventura County; Route 7 extended from Long Beach to Route 210 in South Pasadena; Route 2 to Route 101 completed in North Glendale, Beverly Hills; Route 1 completed in Long Beach; and several additions in San Bernardino and Riverside Counties. There is community opposition to a number of the proposed elements of the network and it is by no means certain that all of "Alternative E-F" will be built as used for 1977 VMT analysis. However, it represents the most conservative (and only) construction assumptions available for analysis. Its limitations must, however, be kept clearly in mind. Because of the lack of other factors, a logarithmic interpolation was used for estimating between 1967 and 1980 in order to arrive at the 1977 estimate VMT.

- Speed

In the basic data provided by the California Division of Highways, the 1967 speeds were running speeds and the 1980 speeds were policy speeds as used by the Highway Division for its forecasts for four classes of road: urban, freeway, rural, and local streets. From this base, the Los Angeles printout for 1967 and 1980 VMT provided for both peak and off-peak speeds. Based on these speeds and the calculation of the share of the eight-hour peak VMT out of the 24-hour total, the following rule was used in obtaining the speed factors for each RAZ:

Peak Hour Speed = Use as the maximum 1-hour speed

Off-Peak Speed = Use as the average 24-hour speed

Midpoint between the Peak and Off-Peak = Use as the Maximum eight-hour speed

- Estimate of One- and Eight-Hour Maximum VMT

Calculation of the required time distributions of VMT was based on 24-hour traffic counts for selected counting stations representing traffic volumes along major corridors in the Los Angeles area. Traffic data for two directions on 18 counting stations were used for the analysis. Major emphasis was given to counting stations involving major flows into the central portions of Los Angeles. All counting stations for which data were available and within the 20 square mile radius were included in the analysis, and selected stations for major traffic points throughout the area were also included.

Based on these traffic counts for 24 hours, the following factors were used in the analysis:

One-hour Peak as a Percent of the 24-hour Total = 7.4 percent
Eight-hour Peak as a Percent of the 24-hour Total = 48.0 percent

- Processing Los Angeles VMT Printout Data Reducing Coverage

Because of the very large area included within the Los Angeles Regional Transportation Study (LARTS) and the relatively sparse population, employment and trip densities for many of the Regional Analysis Zones (RAZ), it seemed advisable to eliminate as many of the RAZ's as possible in order to reduce the number of square mile grids used for analysis. Many of the RAZ's had so few trips (e.g., VMT) and were so large in area that their elimination reduced VMT by very small amounts while cutting the number of grids needed sharply. Furthermore, in view of the fact that emphasis was on the CBD and the peak hour work trips, the eliminated zones assumed even less significance to the analysis. Using the latter as a guide, the RAZ's eliminated (for information purposes SCAG-Southern California Association of Governments-number are shown) are shown below:

SCAG#	RAZ#	SCAG#	RAZ#	SCAG#	RAZ#	SCAG#	RAZ#
1	0100	11	1100	43	4300	48	4810
5	0500	15	1500	44	4400	48	4820
6	0600	30	3010	45	4500	49	4910
7	0700	30	3020	47	4710	49	4920
10	1000	41	4100	47	4720	50	5000

- Calculation of 1967 and 1980 LARTS VMT

Calculation of VMT for each RAZ involved three basic steps: (1) Calculation of interzonal VMT for each of the RAZ's, (2) calculation of intrazonal VMT using intrazonal trip data provided for each RAZ and a factor for counting trip data into VMT also provided by the Division of Highways, and (3) combining inter- and intra-zonal VMT to obtain total VMT for the analysis.

3.6.1.2 Meteorological Data

Annual average wind speeds and directions were obtained from National Climatological data charts. It should be noted that these averages represent typical cases for the area and are applied only to give representative samples of the possible dispersion patterns for the area. The Los Angeles Basin is an area as described in Section 2.3 where physical and meteorological conditions are not adequately represented by the generalized model. Therefore, the "worst case" maximum concentrations predicted are not expected to agree closely with maximum ambient values.

3.6.1.3 Stationary Sources

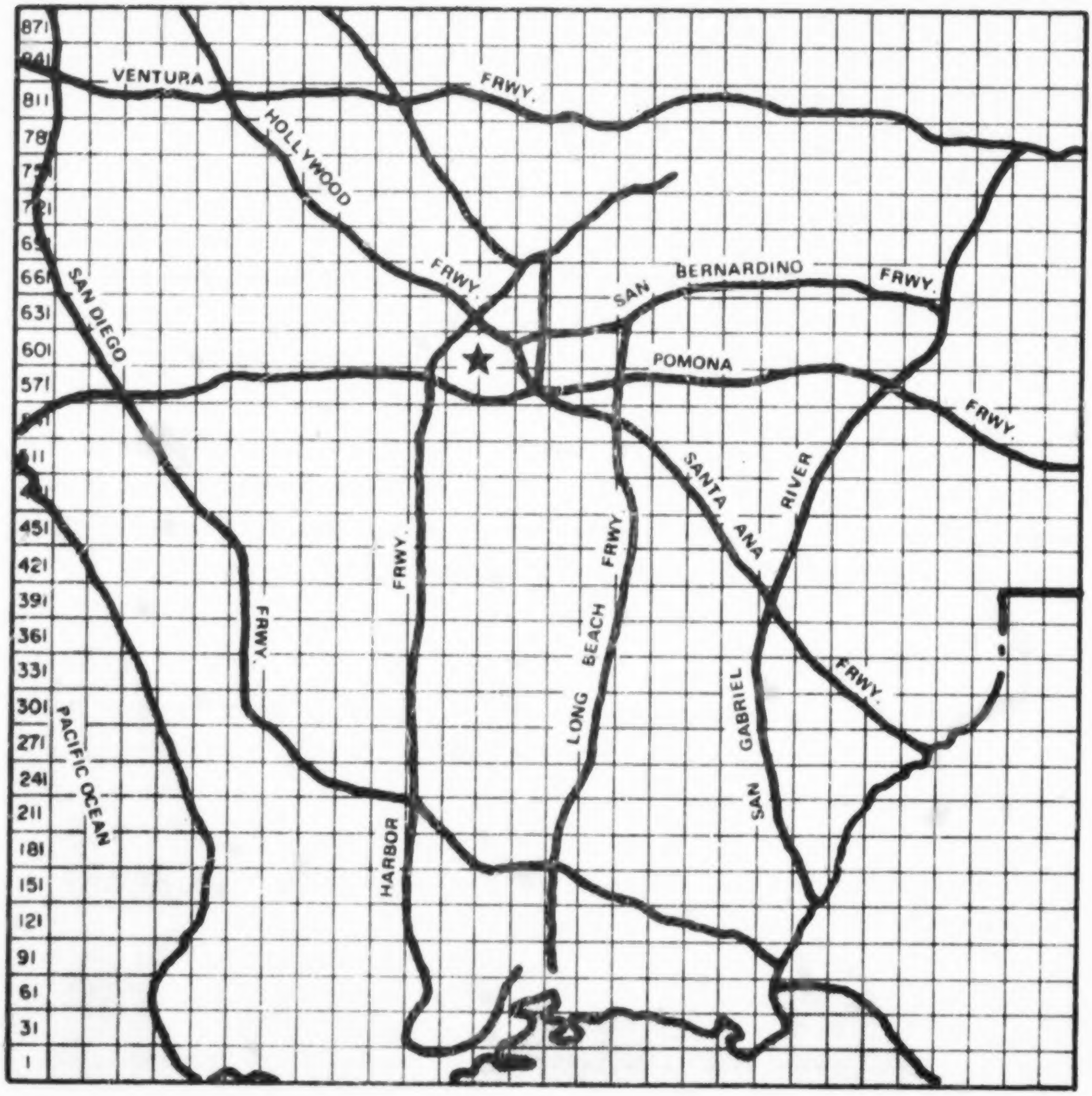
The 1967 stationary sources were estimated as percentages of the total emissions for the area using data supplied by EPA. These percentages were used to calculate the total emissions on a per-grid basis by applying the percentage to the mobile emissions calculated for each grid. The 1977 stationary source emissions were estimated from the state implementation plan.

3.6.2 Summary of Results

The following discussion presents the impact of the transportation controls on each of the three pollutants considered. Figure L.A.1 shows the analysis area.

3.6.2.1 Carbon Monoxide

Table L.A.1 summarizes the maximum emissions and maximum concentrations predicted for carbon monoxide for each of the applied control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SAN DIEGO
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FRWY.
SAN
GABRIEL
HARBOR
PACIFIC OCEAN

Figure L.A.1. Los Angeles Grid Network

Total Area = 900 sq mi

Individual Grid Area - 1 mi^2

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1967	22029 (612)*	21675 (612)	36.1 (571) (601)	51.6 (571) (601)
1977	5977 (612)	5623 (612)	7.3 (601)	24.0 (612)
Strategy 1	5414 (612)	5060 (612)	6.6 (601)	21.7 (612)
Strategy 2	5729 (612)	5375 (612)	6.9 (601)	22.4 (612)
Strategy 3	4949 (612)	4595 (612)	5.9 (601)	19.2 (612)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1967	2183 (571) (601)	1570 (571) (601)	3100 (571) (601)	3700 (571) (601)
1977	1070 (601)	465 (612)	1400 (601)	2400 (571) (601)
Strategy 3	916 (612)	442 (612)	1300 (601)	2300 (571) (612)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures L.A.2, L.A.3, and L.A.4 for location of these maxima for CO, HC, and NO_x, respectively.

Table L.A.1. Predicted Maximum Emissions and Concentrations strategies and the uncontrolled cases. The maximum concentrations are centered in the central business district and near the intersection of major freeway systems as shown in Figure L.A.2.

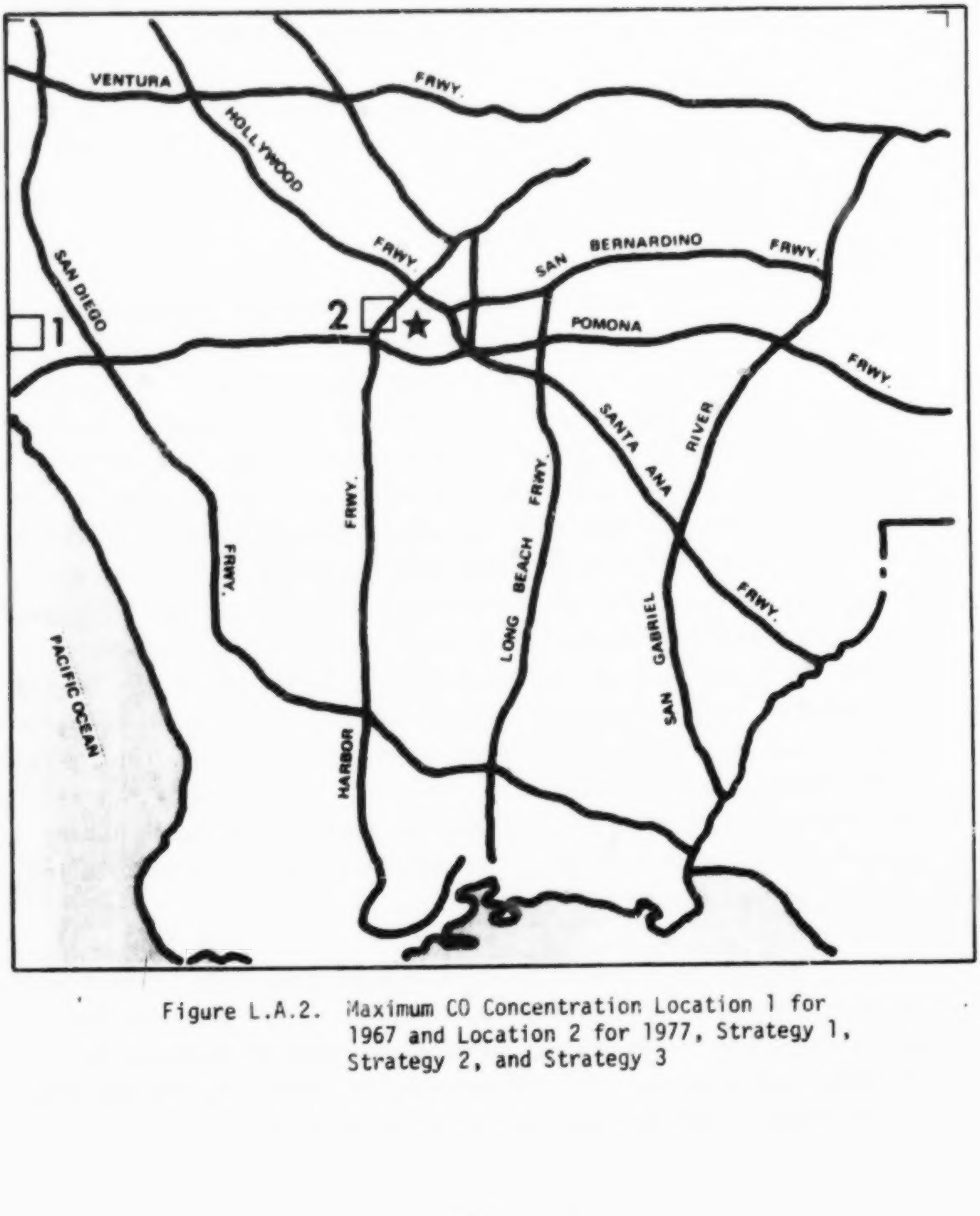
Stationary sources are treated as background emissions as described in Section 3.6.1.3. The procedure does not have a critical effect on CO emissions or concentration patterns in Los Angeles because stationary sources represent an insignificant percentage of total CO emissions in this area.

The 1977 predictions given in Table L.A.1 show the major impact of emission control devices on the maximum eight-hour and peak-hour concentrations. The 1967 maximum emissions are reduced by 74 percent. The reduction appears to be sufficient to reduce concentration maximums to below standard levels; however, under severe stagnation conditions frequently experienced in this area, the eight-hour "worst case" prediction may be exceeded (see Section 2.3).

An inspection and maintenance program (Strategy 1) would reduce the maximum predicted 1977 emissions by approximately 10 percent. This would not have a marked influence on predicted concentrations; however, it would ensure that the automotive emissions did not increase above the level assumed in the uncontrolled case, i.e., that automotive control devices were operating at assumed efficiencies.

Strategy 2 (Traffic Flow Controls) assumes an average increase in vehicle speeds. This strategy would reduce 1977 uncontrolled mobile emissions by approximately five percent. The benefit of this speed increase may be quickly deteriorated by induced traffic volume unless vehicle restraints are applied.

The reduction in mobile source emissions produced by the combined strategies (Strategy 3) is greater than the sum of reductions from the individual strategies because of the added emission reduction achieved by a small percentage VMT reduction. This VMT reduction is a result of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SANTA ANA
FRWY.
RIVER
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LONG BEACH
FRWY.
FRWY.
SAN GABRIEL
PACIFIC OCEAN
HARBOR

Figure L.A.2. Maximum CO Concentration Location 1 for 1967 and Location 2 for 1977, Strategy 1, Strategy 2, and Strategy 3 vehicle restraints applied to maintain the average vehicle speed increase attained through traffic flow controls. The combined emission reduction would be approximately 18 percent of the 1977 uncontrolled vehicle emissions and may be sufficient to maintain maximum concentrations at below standard levels for the "worst case" defined by the model.

Table L.A.3 summarizes the annual emission totals for each pollutant for the entire grid network for each transportation control condition. These values can be used for "rollback" calculations if desired.

3.6.2.2 Hydrocarbons

Table L.A.2 includes the maximum emissions and concentrations predicted for each transportation condition for hydrocarbons. Figure L.A.3 shows the location of the maximum concentrations predicted. It should be recalled that stationary sources are treated as a percentage of the total emissions and vary directly with mobile source emissions (see Section 3.6.1.3). Therefore, although the absolute value of the predicted concentrations is greatly influenced by the stationary sources which contribute approximately 34 percent of the hydrocarbon emissions in the area, the distribution patterns are representative of mobile sources only. It should also be noted that the impact of the stationary source emissions on predicted concentration values increases markedly as automotive emission control is increased. In consideration of these data base features and the distortion of stationary source diffusion characteristics inherent in the ground-level, area source diffusion model, it would be more appropriate to consider the relative reduction in mobile source emissions rather than resultant concentrations for the purpose of analyzing the impact of transportation controls on hydrocarbons.

The 1977 uncontrolled mobile source emissions show a reduction in maximum emissions of approximately 80 percent over 1967 emissions for hydrocarbons. An Inspection and Maintenance program as suggested by Strategy 1 would maintain the efficiency of the control devices and give an additional 12 percent reduction in mobile emissions.

HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1967	5029 (571)[1] (601)	3304 (571) (601)	7600 (571) (601)	9800 (571) (601)	15000 (571) (601)	17000 (571) (601)
1977	2397 (612)	674 (612)	2700 (601)	4300 (571) (601)	5400 (601)	7400 (571) (601)
Strategy 1	2316 (612)	593 (612)	2700 (601)	4000 (571) (601)	5400 (601)	6900 (571) (601)
Strategy 2	2375 (612)	652 (612)	2700 (601)	4100 (601)	5400 (601)	7000 (601)
Strategy 3	2262 (612)	539 (612)	2600 (601	3900 (571) (601)	5200 (601)	6700 (571) (601)

[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures L.A.2, L.A.3, and L.A.4 for location of these maxima for CO, HC, and NO_x, respectively.

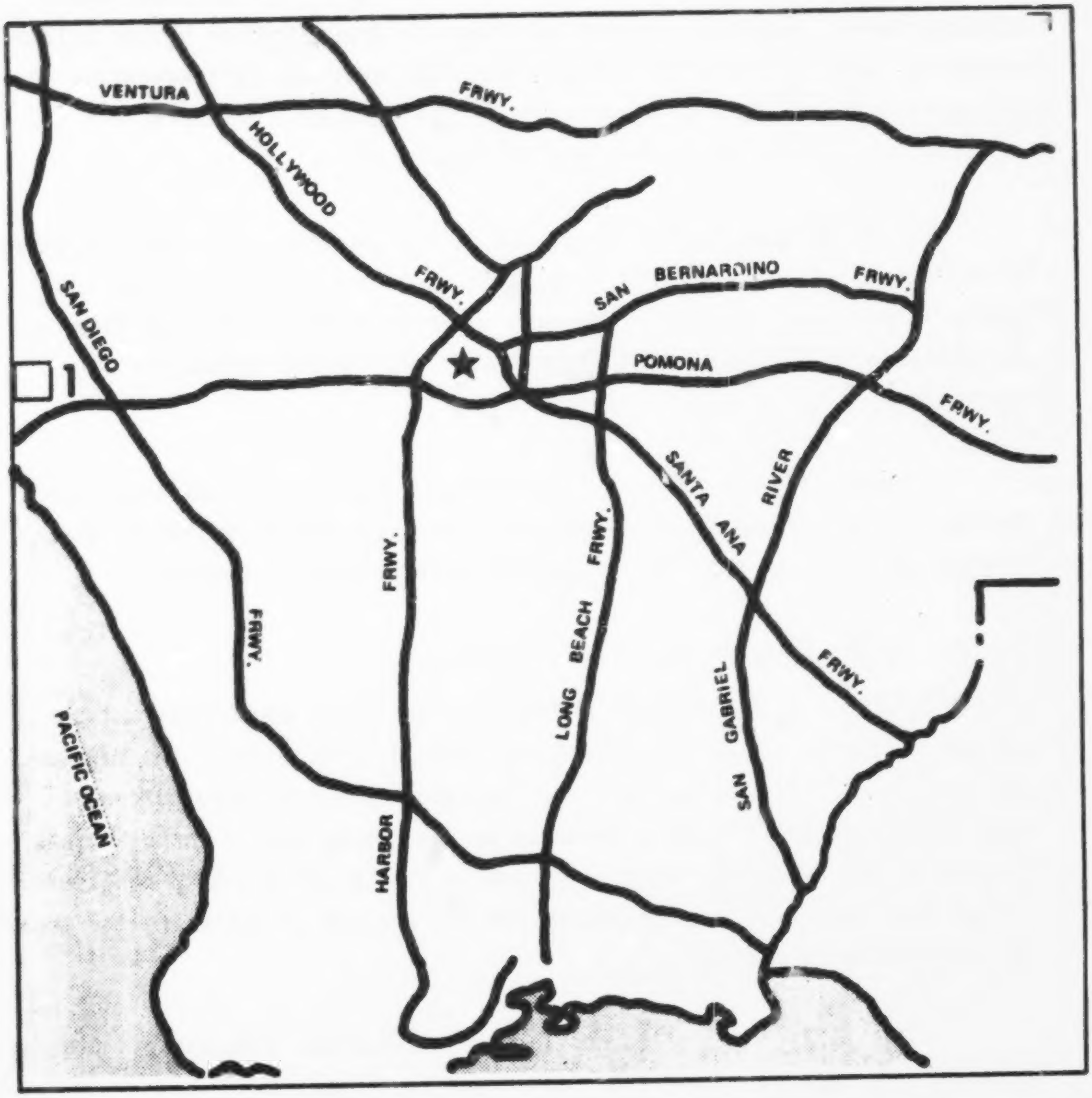
[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table L.A.2. Predicted Maximum Emissions and Concentrations

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1967	2703259	2659900	669174	439632	287097	206423
1977	782050	738734	264478	96453	160512	85598
Strategy 1	708118	664802	252904	84879	NA	NA
Strategy 2	739949	696632	259602	91577	NA	NA
Strategy 3	638886	595570	243449	75424	153176	78262

Table L.A. 3. Annual Emissions (tons/year) for the Area Shown in Figure L.A. 1.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POMONA
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SAN DIEGO
FRWY.
FRWY.
LONG BEACH FRWY.
SANTA ANA
FRWY.
SAN GABRIEL RIVER
HARBOR
PACIFIC OCEAN

Figure L.A.3. Maximum HC Concentration Location for All Transportation Control Conditions Listed in Table L.A.1.

Strategy 2 (Traffic Flow Controls) would reduce 1977 uncontrolled mobile source emissions by approximately four percent. The implied speed increase has very little effect in the Los Angeles areas because the current average vehicle speeds are relatively high. This strategy would probably have a negligible effect on area-wide concentration values unless extensive vehicle restraints are applied. The only apparent advantage to the application of this strategy would be the reduction of short-term concentration values in local areas of congestion.

The combined traffic flow control and vehicle restraints suggested by Strategy 3 would reduce 1977 uncontrolled mobile source emission by approximately eight percent. The major portion of this reduction is attributable to a five percent reduction in VMT implied by vehicle restraints.

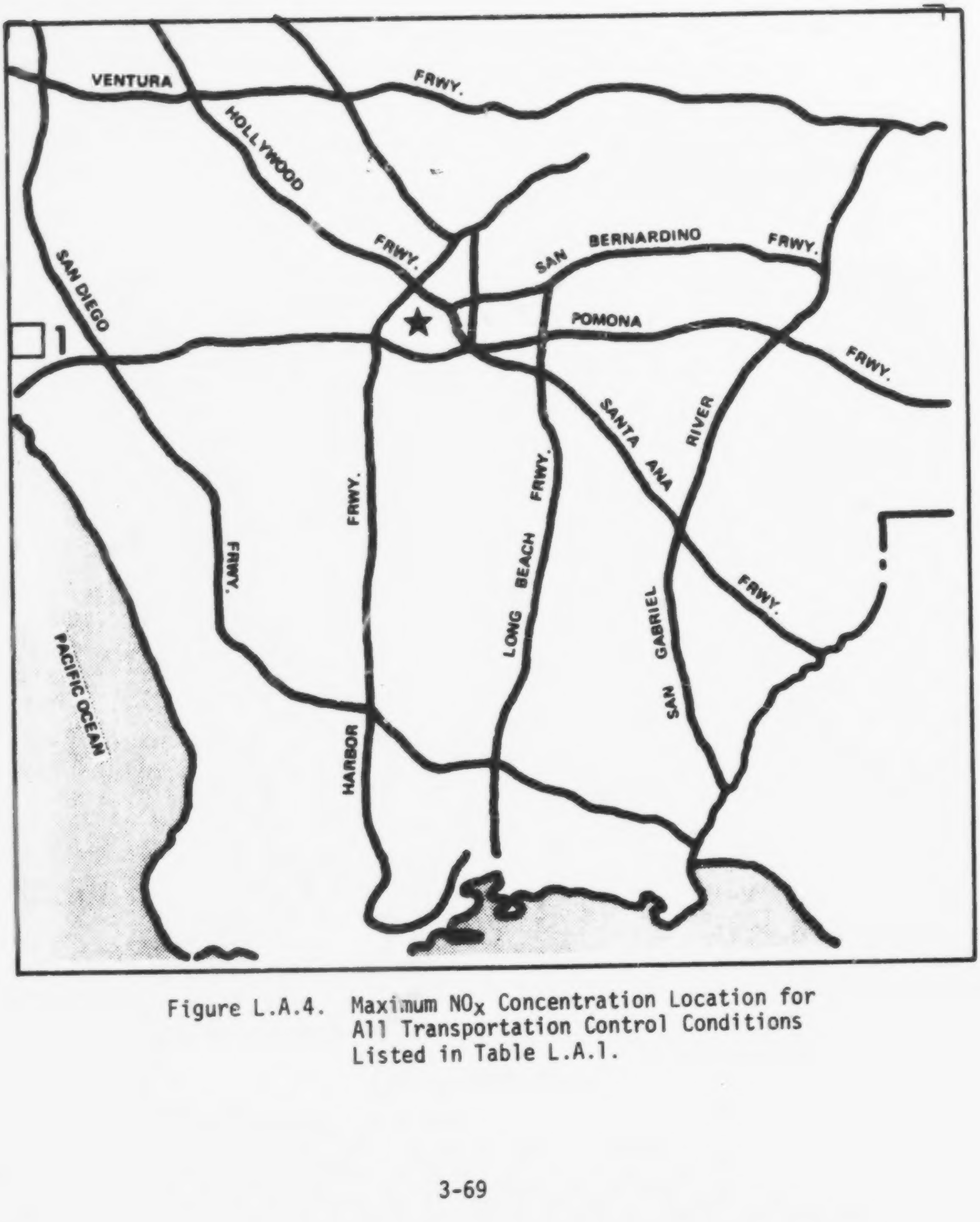
Table L.A.3 summarizes the predicted total annual emissions for the entire 900 square mile grid network. The hydrocarbon emissions given in this table can be used for "rollback" calculations if desired.

3.6.2.3 Oxides of Nitrogen

Table L.A.1 summarizes the maximum emissions and concentrations for NO_x in the grid area. Figure L.A.4 shows the location of the maximum concentrations. It can be seen from the table that predicted concentration values are significantly effected by stationary source contributions. Therefore, the relative reduction in mobile source emissions is considered rather than resultant concentrations for the purpose of analyzing the impact of transportation controls.

The 1977 uncontrolled mobile source emissions show approximately a 70 percent reduction over 1967 mobile source emissions.

Strategy 3 (combined strategies) is the only transportation control strategy with a direct impact on NO_x emissions. The approximately five percent reduction in maximum mobile source 1977 emissions is a result of a small percentage VMT reduction inherent in vehicle restraints.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HARBOR
FRWY.
LONG BEACH
FRWY.
PACIFIC OCEAN

Figure L.A.4. Maximum NO_x Concentration Location for All Transportation Control Conditions Listed in Table L.A.1.

Table L.A.3 summarizes the annual emissions for the entire grid network. The emission totals in this table can be used for "rollback" calculations if desired.

4.0 METROPOLITAN AREA ANALYSIS - WASHINGTON, D.C.
(CASE STUDY)

4.1 DATA BASE AND METHODOLOGY

4.1.1 Transportation Data

- Basic Data

Information relating to VMT and speed were made available in the form of computer printouts from the regional transportation planning agency: The Metropolitan Washington Council of Governments (COG). Specifically, 1968 base year values for peak- and 24-hour VMT were provided. Speed data were not available in usable form, and separate speed estimates were prepared for each zone in the eight rings comprising the Washington Metropolitan Area.

Of considerable importance is the fact that the VMT data provided for the 24-hour period does not include the District city streets. These streets (mostly collectors and distributors) could account for a significant portion of the VMT, and one estimate indicated that close to 40 percent of the 24-hour VMT might be on local city streets not included in the VMT data provided. However, time and budget constraints did not permit estimation of the distribution of these VMT; therefore, calculations were based on the VMT provided by the COG printouts. Clearly, the emission levels are understated because of the missing local street VMT.

- Speed Estimates

Because zonal speed information was not available in a usable form, estimates of average zonal speed were made. These estimates were based on the available data which included (1) the speed data used in coding the links in the traffic assignment model, (2) speed data based on a network transit study, (3) raw data on speed runs using a free floating vehicle method, and (4) maps showing isochrones of travel time for 1959, 1966, 1969 and 1970 prepared. Using the speed maps, speed assignments were made on a zonal basis.

- Projections

Because no projected VMT was available, simple projections to 1977 were made using COG employment projections. Specifically, 24-hour total VMT were summed for each of 146 small planning areas covering the metropolitan area. These figures represent average weekday VMT for 1968. The 24-hour VMT were multiplied by .482, representing the average percent VMT for an eight-hour maximum, to find the average weekday eight-hour maximum VMT for each of the small planning areas. The eight-hour maximum VMT for 1968 were projected to 1976 using the COG small planning area employment projections. The eight-year change was augmented linearly to give a projection for 1977.

For the peak one-hour projections, peak-hour VMT were summed for each of 146 small planning areas covering the metropolitan area. These figures represent average weekday peak-hour VMT for 1968. These peak-hour VMT for 1968 were projected to 1976, again using COG small planning area employment projections; and the eight-year change was again augmented linearly to give a projection for 1977.

It should be noted that this procedure results in a constant ratio of peak-hour VMT to maximum eight-hour VMT for each small planning area. There is, however, an implicit increase in vehicle miles traveled per capita, and even per employed person, because most of the increase takes place in the outlying rings. These outlying rings involve a much higher VMT per person than average for the District.

- Estimates of Eight- and Peak-Hour VMT

"Vehicle Volume Summaries" for the second quarter, 1971, were obtained from the District of Columbia Department of Highways and Traffic for 96 stations in Washington, D. C. Each of these summaries includes weekday average counts (both inbound and outbound) for half-hour periods throughout the day.

Twenty-one major points were selected for calculations. These cover the Washington, D. C., area in grid-like fashion and include most bridges. Vehicle counts for each of the 24 eight-hour periods (beginning on the hour) were calculated. In 11 of the 21 cases, the traffic count was highest in the period 11 a.m. to 7 p.m. In eight cases, the count was highest in the period 12 noon to 8 p.m. In one case, the peak period began at 10 a.m., and in one case at 8 a.m.

The ratio of peak eight-hour traffic ranged from 46.2 percent to 52.0 percent with a mean of 48.2 percent of 24-hour vehicle counts. There is no systematic variation related to distance from the urban core. If the period 11 a.m. to 7 p.m. is selected for all points, the vehicle count is approximately 48 percent of the 24-hour count. Other eight-hour periods are a lower proportion of the total.

4.1.2 Meteorological Data

Wind roses for Washington, D. C., were used to determine the seasonal average wind directions and speeds. It should be noted that these averages may not truly represent the required maximum eight-hour and peak-hour traffic averaging periods. A detailed analysis of the hourly wind data would be required to obtain this accuracy. It should, therefore, be understood that the chosen wind speeds and directions represent typical cases for the area and are applied only to given representative samples of the possible dispersion patterns for the area.

4.1.3 Stationary Sources

Detailed point source data for Washington, D. C., were available and were included in order to give a more realistic projection of concentration values.

Projections for stationary source emissions for the District show a negligible change expected by 1977.

4.2 SUMMARY OF RESULTS

The selected diffusion model was applied to the Washington, D. C., metropolitan area. Four meteorological conditions were considered as follows: (1) Summer wind at 5.5 meters/second, (2) winter wind at 6.6 meters/second, (3) nominal (typical) wind at 5.0 meters/second, (4) "worst case"wind at 2.5 meters/second. Three transportation conditions were considered as follows: (1) Current conditions - as close to present conditions as transportation data allow, in this case 1968; (2) projected transportation conditions for 1977 assuming no additional transportation controls (beyond internal automotive emission controls); and (3) projected conditions for 1977 with estimations of the effects of various transportation controls. Figure D.C. 1 shows the grid system for Washington, D. C., utilized in the model. Isopleths D.C.1 - D.C.33 present isopleths for CO, NO_x, and HC for the meteorological conditions and transportation control conditions listed above.

Both mobile and stationary sources are included as pollutant sources. Mobile sources emit about 99 percent of CO, 88 percent of HC, and 31 percent of NO_x in D.C. area. It is clear that transportation controls will have the greatest impact on CO control and little effect on NO_x control. Also, the assumption of area sources in the model is more nearly true for CO emissions than for HC and NO_x which have significant contribution from point sources. Consideration of large point sources such as electric power generating plants in a particular grid reduces the applicability of the "relatively smooth" assumption in the model. The resulting pollutant concentrations will show a high value in the grid containing the large source and low values in the surrounding grids as if the large source did not exist. This effect should be considered when reviewing the isopleths for HC and NO_x.

The impact of various transportation controls on air quality was estimated. The particular controls to be evaluated were selected as described in Section 2.4 of this report. Although

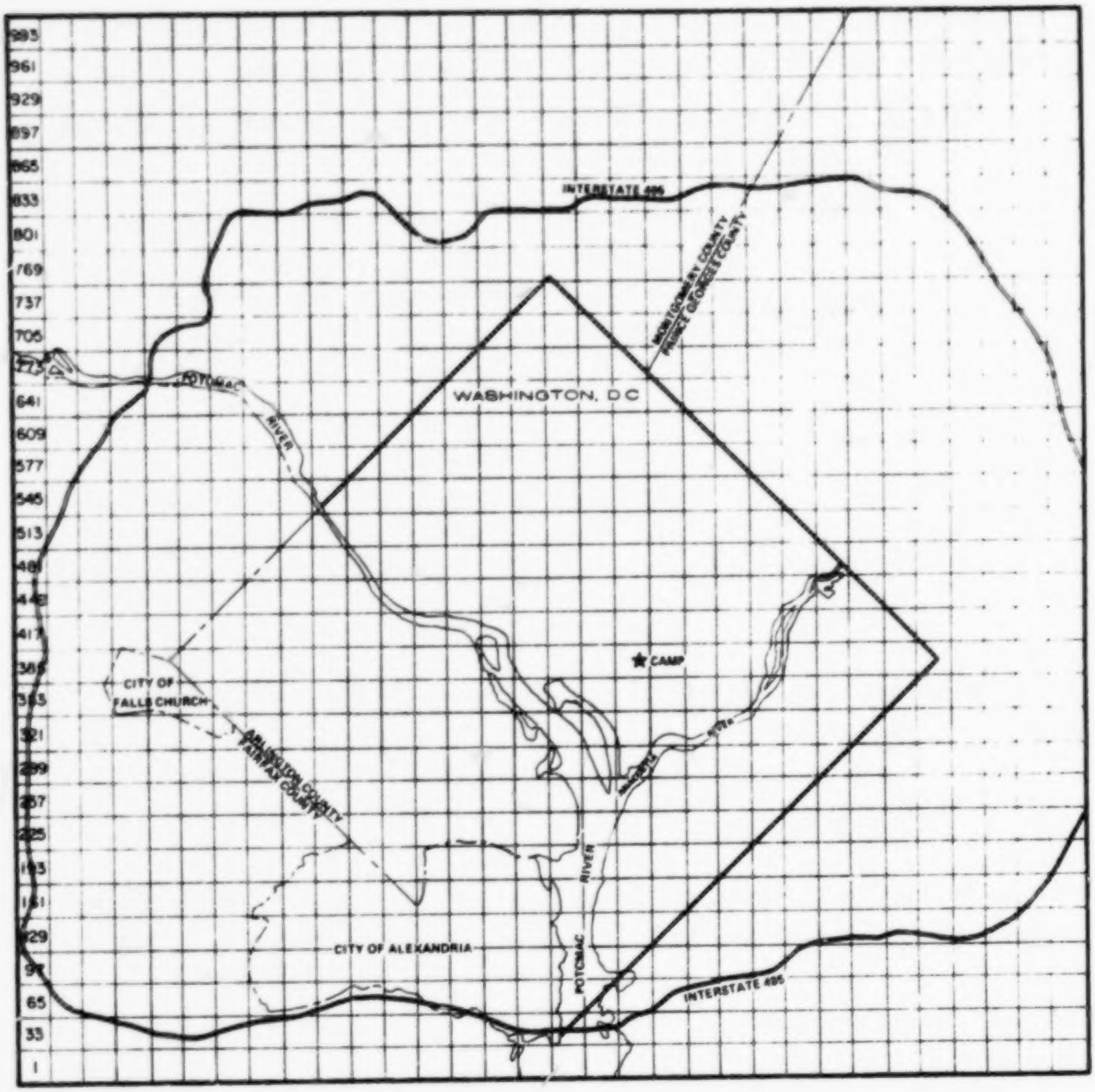
993
961
929
897
865
833
801
769
737
705
673
641
609
577
545
513
481
449
417
385
353
321
289
257
225
193
161
129
97
65
33
1
INTERSTATE 495
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
WASHINGTON, DC
POTOMAC
RIVER
CAMP
CITY OF
FALLS CHURCH
ARLINGTON COUNTY
FAIRFAX COUNTY
ANACOSTIA RIVER
RIVER
POTOMAC
CITY OF ALEXANDRIA
INTERSTATE 495

Figure D.C.1. Grid Network

Total Area = 1024 km^2

Individual Grid Area = 1 km^2

many potential controls were considered, only three were selected for impact calculations due to project limitations. These were:

Strategy 1 - Inspection and Maintenance. This strategy was applied as a reduction in CO emissions.

Strategy 1A - A 25% reduction in CO emissions was used for illustrative purposes.

Strategy 1B - A 10% reduction in CO emissions and a 12% HC reduction was applied as the most likely impact of this strategy.

Strategy 1C - A 5% reduction in CO emissions was applied for illustrative purposes.

Strategy 2 - Traffic Flow Control. Average speeds within each of the speed rings in the original data were increased to indicate the impact of this strategy.

Strategy 3 - Combined Strategies. The impact of Strategy 1B and Strategy 2 were combined with a VMT reduction due to vehicle restraints to produce the most optimistic pattern of emission reductions.

The following represents a discussion of the impact of these control strategies on each of the three pollutants considered.

4.2.1 Carbon Monoxide

Table D.C.1 is a summary of the maximum emissions and maximum concentrations predicted for carbon monoxide for each of the applied control strategies and the uncontrolled cases. The maximum concentrations predicted are given for the "worst case" which is defined by a wind speed of 2.5 m/sec. The maximum concentration for all cases occurs near the center of D. C. in the immediate vicinity of the area of greatest traffic density.

There were no major stationary sources of CO in the immediate vicinity of this maximum concentration area as shown by the mobile and total

CARBON MONOXIDE	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS (mg/m^3)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1968	12589 (433)*	12589 (433)	28.4 (433)	59.1 (433)
1977	4513 (433)	4513 (433)	10.6 (433)	22.1 (433)
Strategy 1A	3384 (433)	3384 (433)	7.9 (433)	16.6 (433)
Strategy 1B	4061 (433)	4061 (433)	9.5 (433)	19.9 (433)
Strategy 1C	4287 (433)	4287 (433)	10.1 (433)	21.0 (433)
Strategy 2	4412 (433)	4412 (433)	10.3 (433)	21.2 (433)
Strategy 3	3687 (433)	3687 (433)	8.4 (433)	17.2 (433)

NITROGEN OXIDES	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)	
	Total	Mobile	8 Hr	1 Hr
1968	6022 (307)	439 (433)	7200 (307)	7500 (307)
1977	6005 (307)	271 (433) (464)	7200 (307)	7300 (307)
Strategy 3	6001 (307)	241 (464)	7200 (307)	7300 (307)

*The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures D.C.2, D.C.3, and D.C.4 for the location of these maxima for CO, HC, and NO_x, respectively.

Table D.C.1. **Predicted Maximum Emissions and Concentrations** emissions; therefore, the maximum concentrations are a result of mobile source emissions only.

The 1977 predictions show the effect of emission control devices on the maximum eight-hour and peak-hour concentrations. The 1968 maximum concentrations would be reduced by nearly two-thirds without the application of any further controls.

Strategy 1 illustrates the possible additional reduction in CO emissions which can be accomplished by implementing an inspection and maintenance program for the D. C. region. This strategy would allow a reduction in CO emissions ranging from 5 percent to 25 percent, with 10 percent being the most likely reduction. A 10 percent reduction in CO emissions would bring the eight-hour concentration maximum slightly below the Federal standard of 10 mg/m^3.

The traffic flow control strategy (Strategy 2) would, in effect, increase the traffic speeds in the downtown area. This would, in turn, decrease the emissions and result in an ∿5 percent decrease in the eight-hour maximum concentration over and above the predicted 1977 concentrations. Without additional traffic controls, this 5 percent decrease would probably disappear within one year due to induced traffic volume increases.

Strategy 3 shows the effect of combining Inspection and Maintenance, (10 percent CO reduction), traffic flow control, and vehicle restraints (10 percent reduction in VMT). The prediction assumes full benefit of all strategies would be achieved in 1977. The resulting maximum eight-hour concentration is approximately a 20 percent improvement over the predicted uncontrolled 1977 concentrations. This would bring the eight-hour maximum concentration safely below the Federal standard.

The general location of the maximum concentrations for each of the transportation conditions is shown for Carbon Monoxide in Figure D.C.-2. Table D.C.-3 summarizes the annual emission totals for the entire grid

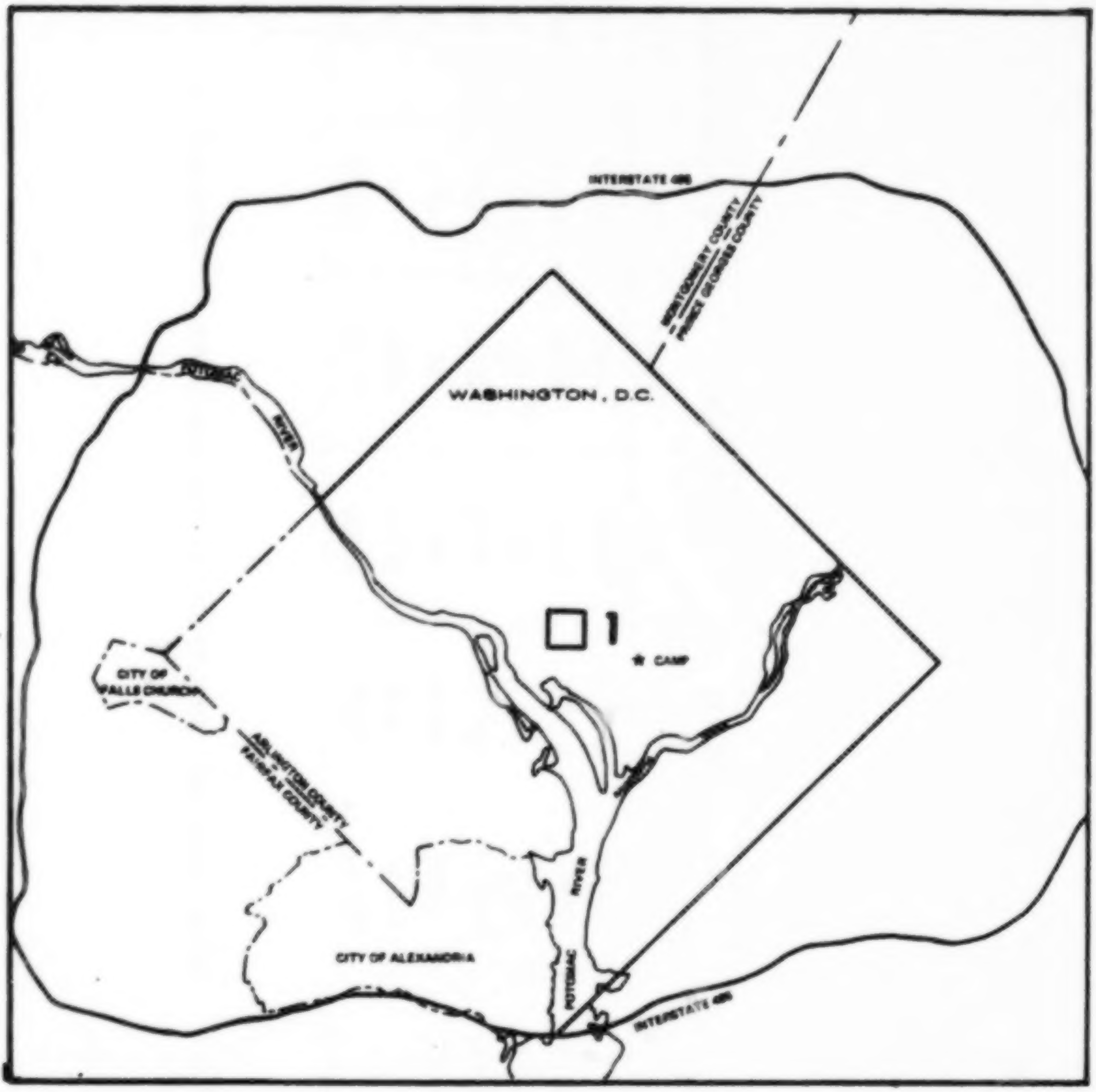
INTERSTATE 495
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
POTOMAC
RIVER
WASHINGTON, D.C.
1
CAMP
CITY OF FALLS CHURCH
ARLINGTON COUNTY
FAIRFAX COUNTY
CITY OF ALEXANDRIA
RIVER
POTOMAC
INTERSTATE 495

Figure D.C.2. Maximum CO Concentration Locations for All Transportation Conditions Given in Table D.C.1

TRANSPORTATION CONDITIONS	CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Total	Mobile	Total	Mobile	Total	Mobile
1968	857422	852838	152577	139957	73922	57029
1977 (uncontrolied)	328065	323481	54457	41844	57639	40900
Strategy 1A (25%)	247189	242606	NA	NA	NA	NA
Strategy 1B (10%)	295715	291132	49436	36823	NA	NA
Strategy 1C (5%)	31188	307304	NA	NA	NA	NA
Strategy 2	303151	298567	51944	39331	NA	NA
Strategy 3	263092	258508	43806	31193	53029	36281

Table D.C.2. Annual Emissions (tons/year) for the Area Shown in Figure D.C. 1.

area for each transportation control condition. Table D.C.3 values can be used for "rollback" calculations for the area.

4.2.2 Hydrocarbons

Table D.C.2 summarizes the maximum emissions and maximum concentrations for hydrocarbons in the grid area. Figure D.C.3 shows the location of these maxima. Note that peak-hour concentrations are given although federal standards are suggested only for a three-hour (6 - 9 a.m.) average. Transportation data given did not allow estimation of concentrations for this specific time period; therefore, the Larsen model was used to estimate the three-hour averages from the predicted eight-hour and one-hour concentrations as shown in Table D.C.2.

It can be seen by the difference in total and mobile source emissions, shown in Table D.C.2, that the maximum concentrations values are greatly affected by stationary sources. For the purpose of analyzing the effect of transportation controls, it is more appropriate to consider the relative reduction in mobile source emissions rather than the reduction in predicted maximum concentrations. The 1977 uncontrolled mobile emissions show a reduction of approximately 70 percent over base year mobile emissions. In the vicinity of the CAMP monitoring station, this reduction would be sufficient to meet the standards; however, near major stationary sources (i.e., National Airport) stationary source and aircraft emissions account for the majority of emissions and the total predicted concentrations are distorted. Therefore, it is difficult to predict the actual concentration reduction achieved.

Inspection and maintenance would reduce mobile source emissions by 12 percent. Traffic flow control (Strategy 2) would have very little effect by itself on mobile sources; however, by combining traffic flow control with vehicle restraints as given by Strategy 3, an additional 12 percent reduction in mobile emissions could be achieved.

HYDROCARBONS	MAXIMUM EMISSIONS (tons/year)		MAXIMUM CONCENTRATIONS ($\mu g/m^3$)(Worst Case)			
	Total	Mobile	8 Hr	1 Hr	3 Hr[2]	3 Hr[3]
1968	2019 (272)[1]	1773 (433)	4100 (433)	8300 (433)	5500 (433)	6700 (433)
1977	1862 (272)	490 (433)	2900 (241)	3100 (241)	3900 (241)	2500 (241)
Strategy 1	1803 (272)	431 (433)	2700 (241)	3000 (241)	3700 (241)	2400 (241)
Strategy 2	1859 (272)	482 (433)	2800 (241)	3100 (241)	3800 (241)	2500 (241)
Strategy 3	1795 (272)	369 (433)	2700 (241)	2900 (241)	3700 (241)	2400 (241)

[1] The numbers which appear in parentheses represent the grid numbers in which the maximum occurs. See Figures D.C.2, D.C.3, and D.C.4 for the location of these maxima for CO, HC, and NO_x, respectively.

[2] Based on conversion of predicted concentration for eight-hour average by Larsen's method.

[3] Based on conversion of predicted concentration for one-hour average by Larsen's method.

Table D.C.3. Predicted Maximum Emissions and Concentrations

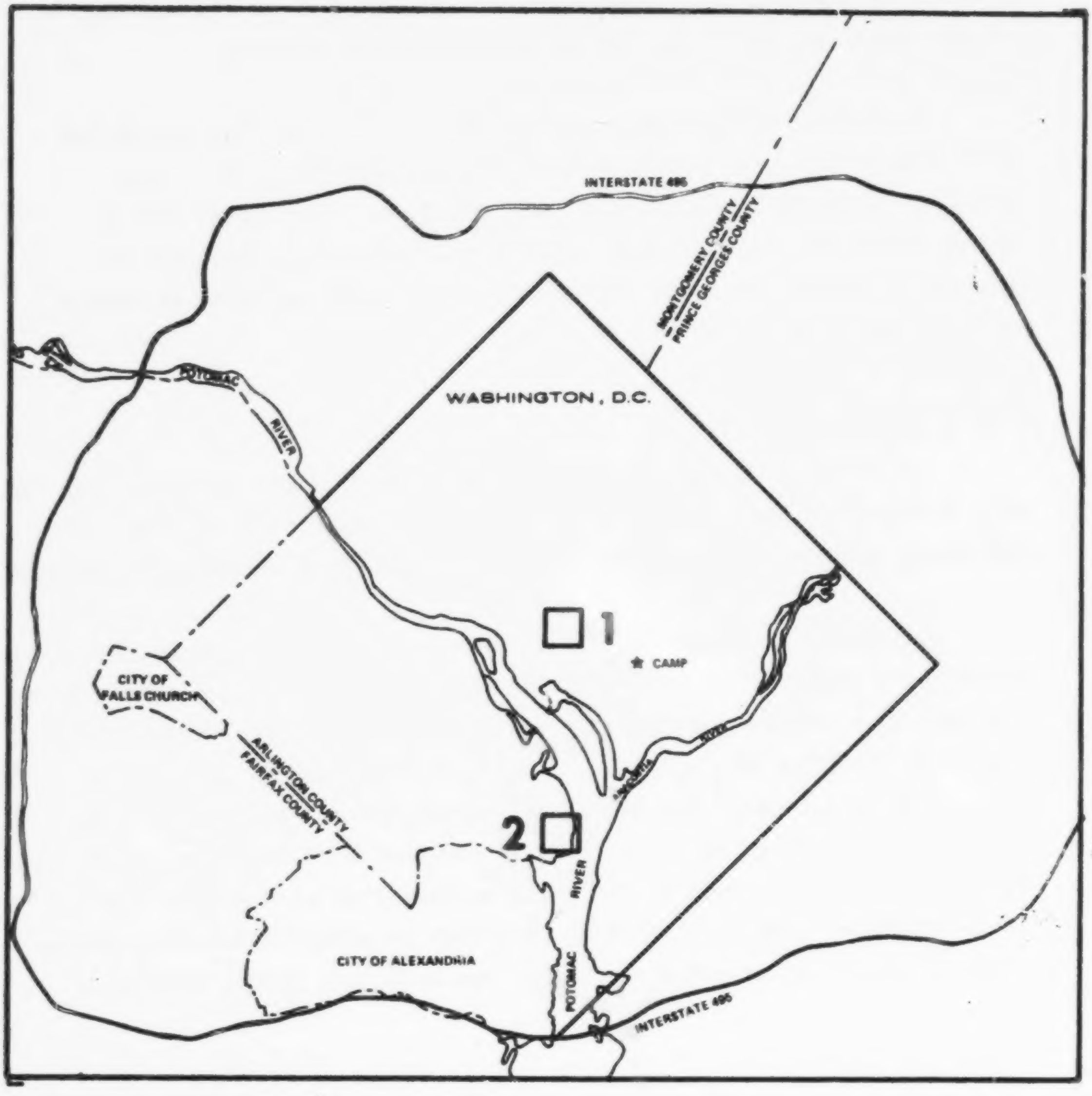
INTERSTATE 495
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
POTOMAC
RIVER
WASHINGTON, D.C.
1
CAMP
CITY OF FALLS CHURCH
ARLINGTON COUNTY
FAIRFAX COUNTY
ANACOSTIA RIVER
2
RIVER
POTOMAC
CITY OF ALEXANDRIA
INTERSTATE 495

Figure D.C.3. Maximum HC Concentration Location 1 for 1968 Uncontrolled Location 2 for All Other Transportation Conditions Given in Table D.C.1.

The distribution of resultant hydrocarbon concentrations is given in the isopleth patterns in Appendix A. Obviously, these patterns are grossly affected by major stationary sources and are not representative of the impact of mobile sources or transportation controls.

Table D.C.3 lists the predicted annual emissions for the entire grid network for each transportation control condition. Both total emissions and mobile source emissions are given. The annual mobile source emissions in this table could be used in conjunction with a detailed inventory of other sources to obtain total emission estimates for "rollback" calculations.

4.2.3 Oxides of Nitrogen

Table D.C.1 summarizes the maximum concentrations and emissions for NO_x in the grid area. Figure D.C.4 shows the location of the areas of predicted maximum concentrations for each transportation control condition.

It can be seen from the table that the predicted maximum concentrations are a result of emissions from large stationary sources included in the data base. Maximum concentrations resulting from the maximum mobile source emissions given in the table would be approximately 60 percent less or about 3.0 mg/m^3 for the eight-hour maximum concentration. For the purpose of analyzing the effect of transportation controls, it may be more appropriate to consider the relative reduction in mobile source emissions rather than the relative reduction in predicted maximum concentrations which are so grossly affected by stationary source emissions.

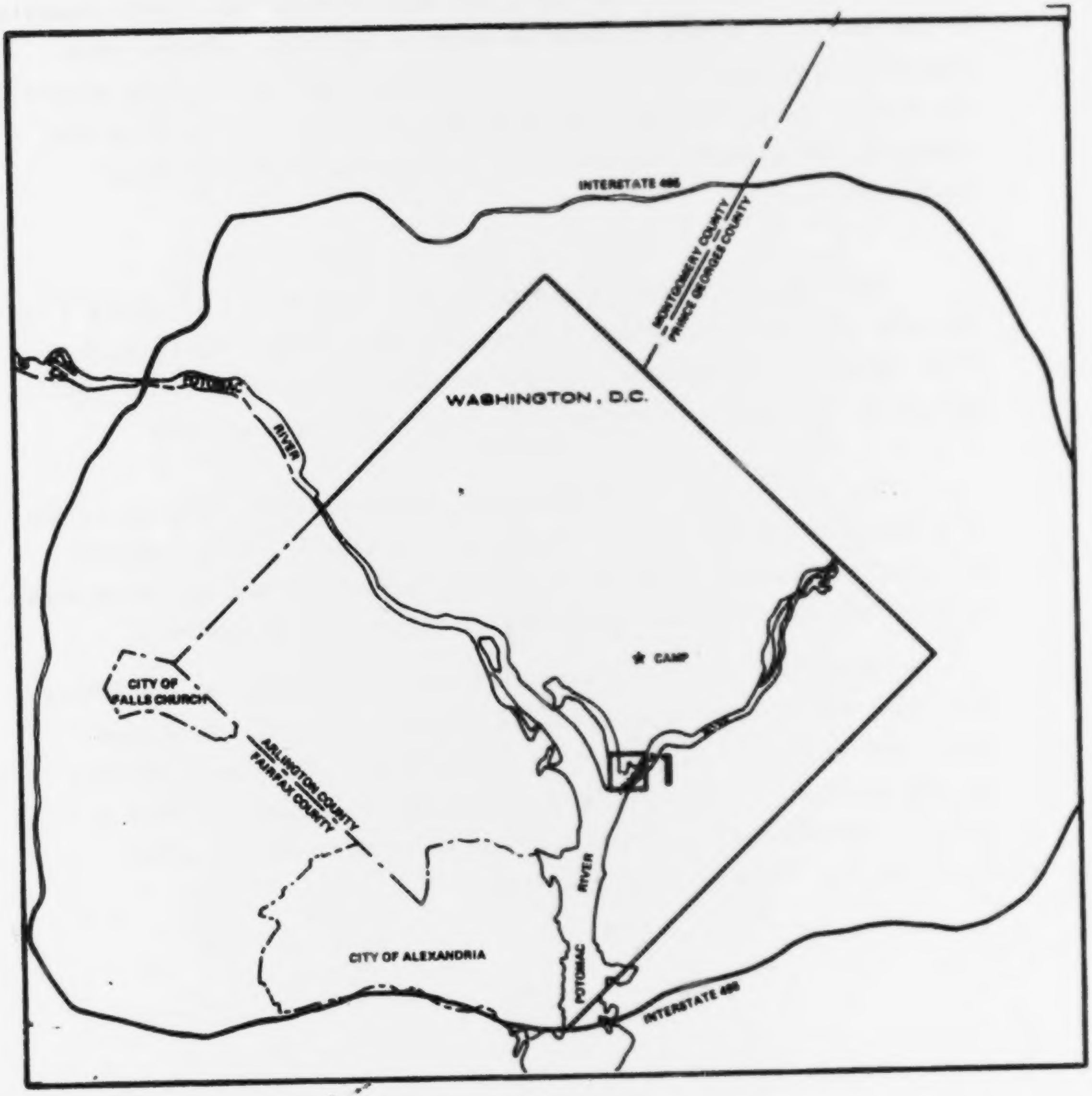
INTERSTATE 495
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
POTOMAC
RIVER
WASHINGTON, D.C.
CAMP
CITY OF FALLS CHURCH
ARLINGTON COUNTY
FAIRFAX COUNTY
RIVER
POTOMAC
CITY OF ALEXANDRIA
INTERSTATE 495

Figure D.C.4. Maximum NO_x Concentration Locations for All Transportation Conditions Given in Table D.C.1.

The 1977 uncontrolled mobile emissions show a maximum reduction of approximately 40 percent over base year mobile emissions. This reduction is due solely to direct automotive emission controls. Whether this reduction alone would be sufficient to bring actual air quality within the federal guidelines would be dependent on the extent to which the standards are exceeded and the 1977 contribution from stationary source emissions.

Strategy 3 (combined emission and traffic control strategies) is the only transportation control strategy with a direct impact on NO_x emissions. The approximately 10 percent additional reduction in mobile emissions is a result of reduced VMT due to vehicle restraints.

The distribution of predicted NO_x concentrations is given in the isopleth patterns for NO_x in Section 4.4. Obviously, these patterns are grossly affected by major stationary sources and are not representative of the impact of mobile sources or transportation controls.

Table D.C.3 lists the predicted annual emissions for the entire grid network for each transportation control condition. Both total emissions and mobile source emissions are given. The annual mobile source emissions in this table could be used in conjunction with a detailed inventory of other NO_x sources to obtain total emission estimates for "rollback" calculations.

4.3 COMPARISON OF CALCULATED CONCENTRATIONS WITH AMBIENT MEASUREMENTS

It is of interest to compare the calculated concentrations value with the available measurements of air quality.(1) The available data for Washington, D.C., which are those from the CAMP station in grid number 403 of Figure D.C.1, were obtained from the D.C. Bureau of Air and Water Quality Control. The CAMP station data show worst case one-hour and eight-hour averages for CO of 50 and 32 mg/m^3 and nominal values in the ranges of 22 to 40 and 10 to 12 mg/m^3. The calculated values agree quite closely with those as shown in Table D.C.4.

CAMP station data for non-methane type hydrocarbons are given in Table D.C.4. The basic modeling assumptions and variables as well as ambient measurement methods should be carefully reconsidered before comparing the calculated values with ambient values. As explained in the preceding discussion of methodology, the area source assumption is more valid for CO than for HC or NO_x. Grids containing large stationary sources create small anomalous regions in the generally smooth isopleth pattern. This distortion would be more prominent in the HC and NO_x isopleths because of the large percentage of their emissions due to stationary sources.

The HC and NO_x are chemically and photochemically reactive species and the products of these reactions are dependent on many variables, including radiation input and time. These variables are not explained by the Gifford-Hanna model and, in fact, can only be explained by complex chemical reaction models requiring data input which are not readily available for most cities.

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(1) Comparison of ambient data with predicted data required that sufficient data for each pollutant be available for the specific time period required by the model, i.e., the maximum eight-hour traffic period and the peak traffic hour. Most major cities do maintain records of ambient concentrations for each of the three pollutants in some form; however, the data are rarely available for the time periods required. Comparison of predicted values for Washington, D.C., with ambient data was made possible through discussions with D.C. air quality control personnel intimately familiar with the data, who reviewed the available original recorded data charts or applied their familiarity with the data to obtain estimates of the concentration averages most representative of the time period desired.

CARBON MONOXIDE (CO)
(mg/m^3)

	Eight Hour		One Hour	
	Nominal	Maximum	Nominal	Maximum
CAMP	10-12	32	22-40	50
Predicted	8-12	24	18-24	51
Standard	10		40	

HYDROCARBONS (HC)
(mg/m^3)

	Total	Non-Methane
CAMP	1.3 - 2.0 (maximum)	.33(6-9a.m.) (maximum)
Predicted		5.7 (3 hr. avg.)
Standard		.16(6-9a.m.)

NITROGEN OXIDES (NO_x)
(mg/m^3)

	NO_2	NO_x
CAMP	.12(8-hr. max.)	.4-.8(8-hr. est. max.)
Predicted (NO_x as NO_2)		.9(8-hr. max.)
Standard	.1(8-hr. annual mean)	

Table D.C.4. Washington, D.C., 1968 Ambient and Predicted Pollutant Concentrations at the CAMP Station

The impact of the unexplained variables and deviation from model assumptions appears to be greatest for the hydrocarbons as seen in Table D.C.3. The model utilizes emissions from mobile sources, which are predominantly non-methane hydrocarbons, to predict air quality. Since the methane fraction of the total emissions is very small compared to the non-methane emissions, removal of the methane fraction as input to the model would not totally explain the gross disparity in calculated air quality as compared to ambient measurements of non-methane hydrocarbons. Comparison of predicted values with total hydrocarbons would have to account for the large amount of ambient methane measured.

Ambient nitric oxide values and nitrogen dioxide values are given in Table D.C.3. NO_x is not routinely monitored at the CAMP station. To compare with the NO_x ambient air quality as calculated by the model, an estimate of nominal NO_x ambient air quality is also given in the table. Air quality standards are written for NO_2 although the model emission factors are given for NO_x as NO_2; the reason for this being that NO_2 is a secondary pollutant and the model cannot explain atmospheric reactions. Therefore, the model output should, perhaps, be compared to NO_x values rather than ambient NO_2 avalues. A rough estimate of NO_x is obtained from the nitric oxides and NO_2 ambient measurements at the CAMP station. Comparison of these values still shows a large unexplained discrepancy. Deviation from the area source assumption is most obvious in the NO_x emissions (see Section 2.1); however, the extent or the impact of this deviation on the calculated air quality values cannot be quantitatively determined due to the complex nature of the other unexplained variables such as atmospheric reactions.

In summary, carbon monoxide is the gaseous pollutant which is most compatible with the basic modeling assumptions; and the basic agreement of ambient carbon monoxide measurements with the calculated air quality is felt to recommend the modeling approach selected for carbon monoxide for D.C. The hydrocarbons and NO_x deviate from some of the basic modeling assumptions or parameters. A quantitative analysis of these deviations would require many more ambient samples which are not available for D.C. and a detailed study of such factors as atmospheric reactions and ambient monitoring methods which is beyond the scope of this current study. The model does indicate the areas of worst case emissions for hydrocarbons and NO_x and could be used as a "first guess" indicator of air quality in these worst case areas; however, the numerical values of the predicted air quality for these pollutants would not be reliable.

APPENDIX A
WASHINGTON, D.C., ISOPLETHS*

The following isopleths are representative of the dispersion patterns estimated for each pollutant for each of the given transportation conditions.

Isopleths D.C.1 - D.C.8 represent the current carbon monoxide eight-hour and peak-hour concentration patterns for each of four meteorological conditions. Case 4 is the "worst case" as described in the text. Cases 1, 2, and 3 are given to illustrate representative dispersion patterns.

Isopleths D.C.9 represents the one-hour "worst case" 1968 HC dispersion pattern.

Isopleth D.C.10 represents the eight-hour "worst case" 1968 NO_x concentration pattern.

Isopleth D.C.11 - D.C.18 are the 1977 uncontrolled carbon monoxide concentration patterns for those cases discussed above for 1968.

Isopleth D.C.19 shows the one-hour "worst case" 1977 uncontrolled HC concentration pattern.

Isopleth D.C.20 represents the eight-hour "worst case" 1977 uncontrolled NO_x concentration pattern.

Isopleths D.C.21 - D.C.26 show the effects of Strategy 1A, 1B, and 1C on CO "worst case" concentrations.

Isopleths D.C.27 - D.C.29 represent Strategy 2 impact on CO and HC "worst case" concentrations.

Isopleths D.C.30 - D.C.33 represent Strategy 3 impact on CO, HC, and NO_x "worst case" concentrations.

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*Isopleths for the other five metropolitan areas are available upon request.